Curriculum of Diploma Programme

in

Ceramics Engineering

Department of Science,

Technology and Technical Education (DSTTE),

Govt. of Bihar

State Board of Technical Education

(SBTE), Bihar

Semester – IV
Teaching & Learning Scheme

Course Codes	Category of course	CourseTitles	Teaching & Learning Scheme (Hours/Week)					
			Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
			L	T				
2413401	**PCC**	**Geology for Ceramics Engg**	03	-	04	02	09	06
2413402	**PCC**	**Chemistry for Ceramics Engg.**	03	-	04	02	09	06
2413403	**PCC**	**Ceramic Processing**	03	-	04	02	09	06
2413404	**PCC**	**Pottery and Porcelain Tech.**	03	-	04	02	09	06
2413405	**PCC**	**Advance Refractory Tech.**	03	-	04	02	09	06
Total			**15**	**-**	**20**	**10**	**45**	**30**

Note: Prefix will be added to Course Code if applicable (T for Theory Paper, P for Practical Paper and S for Term Work)

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

Semester - IV
Assessment Scheme

Course Codes	Category of course	Course Titles	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
			Theory Assessment (TA)		Term work & Self-Learning Assessment (TWA)		Lab Assessment(LA)		
			Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2413401	**PCC**	**Geology for Ceramics Engg.**	30	70	20	30	20	30	200
2413402	**PCC**	**Chemistry for Ceramics Engg.**	30	70	20	30	20	30	200
2413403	**PCC**	**Ceramic Processing**	30	70	20	30	20	30	200
2413404	**PCC**	**Pottery and Porcelain Technology**	30	70	20	30	20	30	200
2413405	**PCC**	**Advance Refractory Technology**	30	70	20	30	20	30	200
Total			**150**	**350**	**100**	**150**	**100**	**150**	**1000**

Note: Prefix will be added to Course Code if applicable (T for Theory Paper, P for Practical Paper and S for Term Work)

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar, and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

A) Course Code : **2413401(T2413401/P2413401/S2413401)**

B) Course Title : Geology for Ceramic Engineering

C) Pre- requisite Course(s) :

D) Rationale :

The field of geology has significant importance in establishing the fundamental knowledge base for students pursuing a diploma in ceramic engineering. The inclusion of a complete geology course within the curriculum offers several advantages that are crucial for the well-rounded education of aspiring ceramic engineers. Geology is the science of Earth. Geology plays a crucial role in various stages of ceramic engineering, from the sourcing of raw materials to the manufacturing processes and product development. It provides geological aspects related to the production of ceramic materials and products.

E) Course Outcomes (COs): After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- **CO-1** Use geological ideas to find ceramic raw material sources and assess their geological properties and industrial applicability.
- **CO-2** Select suitable rocks and minerals and their significance in construction, industry, and other applications.
- **CO-3** Select rock-forming and ore-forming minerals based on their physical and chemical properties.
- **CO-4** Select the suitable geological method for material formation, site selection, and risk assessment.
- **CO-5** Analyze natural processes and volcanic eruptions' sources, impacts, geological importance, and environmental and socioeconomic dangers.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	**PO-2** Problem Analysis	**PO-3** Design/ Development Solutions	**PO-4** Engineering Tools	**PO-5** Engineering Practices for Society, Sustainability and Environment	**PO-6** Project Management	**PO-7** Life Long Learning	**PSO-1**	**PSO-2**
CO-1	3	-	1	-	-	-	2		
CO-2	3	2	2	2	-	-	1		
CO-3	3	2	-	2	-	-	2		
CO-4	3	2	1	-	2	2	-		
CO-5	3	-	-	-	2	-	2		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2413401	Geology for Ceramic Engineering	03	-	04	02	09	06

Legend:

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Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2413401	Geology for Ceramic Engineering	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in classroom (includes class test, mid-term test, and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

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I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2413401

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain geology and its importance on Earth. *TSO 1b.* Differentiate physical geology, historical geology, mineralogy, and petrology *TSO 1c.* Analyze geology's uses in building, environmental science, and ceramics. *TSO 1d.* Explain our solar system, including the Sun, planets, and other celestial bodies. *TSO 1e.* Explain Earth's atmosphere, hydrosphere, lithosphere, and biosphere. *TSO 1f.* Describe the Earth's crust, mantle, and core, focusing on its internal structure.	**Unit-1.0 Introduction to Geology** 1.1 Definition and scope of geology 1.2 Branches of geology: physical geology, historical geology, mineralogy, and petrology. 1.3 Importance of geology in various fields, including ceramics 1.4 Our Solar System, Parts of Earth, atmosphere, hydrosphere, lithosphere, biosphere, and Age of Earth 1.5 Earth structure: Crust, Mental, Core 1.6 Member of solar system	**CO1**
TSO 2a. Describe crystals and their elements. *TSO 2b.* Explain crystallographic axes, axial symmetry, and interfacial angles. *TSO 2c.* Explain mineralogy and its significance in the study of Earth's composition. *TSO 2d.* Classify minerals based on their physical characteristics. *TSO 2e.* Classify rocks based on their origin into igneous rocks, sedimentary rocks, and metamorphic rocks. *TSO 2f.* Explain the formation processes, classification criteria, and texture and structure characteristics of rocks. *TSO 2g.* Explain the rock cycle, and its link to the three main rock kinds.	**Unit-2.0 Mineralogy and Petrology** 2.1 Crystallography-Definition of crystal, elements of crystal, crystallographic axes, axial & symmetry character, interfacial angle, crystal system. 2.2 Mineralogy- Definition, Physical properties of minerals such as habit, color, streak, crystal system, luster, cleavage, fracture, hardness, specific gravity, magnetism. 2.3 Petrology- Definition of a rock, Classification of rocks based on their origin, igneous rock, Sedimentary rock, metamorphic rock, its formation, classification, texture & structure, Forms of igneous rock, Uses, Rock cycle.	**CO2**
TSO 3a. Describe rock forming minerals such as quartz, orthoclase, microcline, mica, olivine, garnet, calcite, dolomite, gypsum, kyanite, sillimanite, andalusite, beryl, fluorite, zircon, corundum, and topaz. *TSO 3b.* Explain the physical and chemical characteristics of minerals and their role in rock formation and categorization. *TSO 3c.* Describe ore-forming minerals such as bauxite, witherite, barite, chromite, hematite, magnetite, galena, magnesite, graphite, diamond, and gold. *TSO 3d.* Describe the geological processes that generate these mineral ore deposits.	**Unit-3.0 Rocks and Minerals** 3.1 Rock forming group: Quartz, Orthoclase, Microline, Mica, Olivine, Garnet, Calcite, Dolomite, Gypsum, Kyanite, Sillimanite, Andalsuite, Beryl, Fluorite, Zircon, Corundum, Topaz 3.2 Ore forming group: Bauxite, Witherite, Barite, Chromite, Hematite, Magnetite, Galena, Magnesite, Graphite, Diamond, Gold	**CO3**
TSO 4a. Explain physical geology and its relevance to ceramic engineering. *TSO 4b.* Analyze the geological processes driven by wind, rivers, glaciers, and seas, and their impact on shaping the Earth's surface. *TSO 4c.* Explain the relevance of economic geology in resource discovery and use. *TSO 4d.* Describe important economic mineral deposits in India, including gold, copper, aluminum, iron, manganese, chromium, lead, zinc, coal, and petroleum.	**Unit-4.0 Geological Methods** 4.1 Physical geology: Introduction, geology and its relevance to ceramic engineering, geological work of wind, rivers, glaciers and seas. 4.2 Economic Geology: Definition & its importance, classification of mineral deposits, Important economic mineral deposits of India such as gold, copper, alluminium, iron, manganese, chromium, lead, zinc, coal, petroleum.	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 4e. Describe the geological factors considered while designing and building tunnels, dams, bridges, and other structures. *TSO 4f.* Explain structural geology and its role in Earth's crust.	4.3 Engineering Geology: geological considerations in tunnels, dams, bridges, building sites; landslides. 4.4 Structural Geology: Introduction, dip, apparent dip & true dip, strike, definition, parts & types of folds, faults & joints.	
TSO 5a. Explain air and rain-induced rock weathering. *TSO 5b.* Explain rivers, lakes, and oceans, formation processes. *TSO 5c.* Differentiate between various types of earthquakes and their causes. *TSO 5d.* Explain the fundamental principles of tsunamis, including their causes and effects. *TSO 5e.* Explain the causes and effects of avalanches, particularly in mountainous regions.	**Unit-5.0 Natural process and Hazards** 5.1 Weathering of rocks: air, rain 5.2 Rivers, Lakes, Oceans 5.3 Earthquake: basic definitions, types and causes, distribution in the world, seismic zones. 5.4 Tsunami: Definitions, causes and effects. 5.5 Volcano: Definition causes and effects. 5.6 Avalanches: Definition, causes and effects.	**CO5**

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2413401

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Operate the Steel Yard's apparatus correctly and safely, including the proper handling of weights and materials. *LSO 1.2.* Calculate the unknown material's specific gravity using the data. *LSO 1.3.* Use the material's density and composition to interpret the specific gravity value.	1.	• Determination of specific gravity of unknown material by steel yard's apparatus.	CO2
LSO 2.1. Use the Steel Yard's equipment to zero the balance, hang masses, and measure the feldsphar sample's volume by immersion. *LSO 2.2.* Calculate the feldspar sample's specific gravity using experiment results. *LSO 2.3.* Draw inferences about the sample's density and composition from the data.	2.	• Determination of specific gravity of feldspar by steel yard's apparatus.	CO2
LSO 3.1. Use the Steel Yard's equipment to zero the balance, hang masses, and measure the alumina sample's volume by immersion. *LSO 3.2.* Calculate the alumina sample's specific gravity using experiment results.	3.	• Determination of specific gravity of alumina by steel yard's apparatus.	CO2
LSO 4.1. Use the Steel Yard's equipment to zero the balance, hang masses, and measure quartz sample volume by immersion. *LSO 4.2.* Calculate the quartz sample's specific gravity using experiment results.	4.	• Determination of specific gravity of quartz by steel yard's apparatus.	CO2

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 5.1. Use the Steel Yard's equipment to zero the balance, hang masses, and measure quartz sample volume by immersion. *LSO 5.2.* Calculate the magnesite sample's specific gravity using experiment results.	5.	• Determination of specific gravity of magnesite by steel yard's apparatus.	CO2
LSO-6.1. Compare the hardness of unknown minerals with the known hardness values of common reference minerals on the Mohs Scale. *LSO-6.2.* Select suitable material for abrasion test.	6.	• Determination of the hardness of any unknown minerals.	CO2
LSO-7.1. Determine the physical properties of unknown minerals. *LSO-7.2.* Compare mineral identification qualities such as color, streak, hardness, cleavage, fracture, luster, and specific gravity.	7.	• Identification of unknown mineral by physical properties.	CO2

L) Suggested Term Work and Self Learning: S2413401 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

1. Identify and describe ceramic engineering minerals.
2. Explain their crystal formations, physical characteristics, and ceramic manufacturing importance.
3. Select a ceramic production location and identify prospective raw material sources, analyze geological dangers, and suggest justifying measures after evaluating the geological composition.

b. Micro Projects:

1. Identify and analyze various minerals commonly used in ceramics production (e.g., feldspar, kaolin, quartz) using mineral identification techniques and prepare a report on it.
2. Conduct physical property tests (hardness, streak, cleavage, specific gravity) on mineral samples and correlate the results with their suitability for ceramic applications and prepare a report and represent it in the class.
3. Conduct a geological field mapping project in a local area and prepare a report.
4. Collect mineral samples, perform physical property tests (hardness, streak, cleavage, etc.), and categorize the minerals based on their properties and prepare a report.

c. Other Activities:

1. Seminar Topics:
   - Naturally occurring raw materials and synthetic raw materials in India.
   - Raw materials import and export in India.
   - Major application areas of ceramics.
   - Advance Ceramic / Modern Ceramic
   - Ceramics in Medical Sector
   - Invite experts from ceramic industry, academia, or research institutions to give lectures on advanced ceramics, sustainable practices and innovative applications.

2. Visits:
   - Visit a designated geological site, record rock types, structures, and geological features, and create detailed geological maps and cross-sections.

   Plan visits to ceramic manufacturing facilities located near geological sites. Students can observe the extraction processes, material testing labs, and quality control measures in place.

3. Self-Learning Topics:
   - Geological Field Mapping.
   - Geological Aspects of Natural Resource Management.
   - Geological conditions (e.g., soil type, slope angle).

M) **Suggested Course Evaluation Matrix:** The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	**25%**	**20%**	**15%**	20%	20%	-	-
CO-2	25%	20%	10%	20%	20%	100%	100%
CO-3	10%	15%	15%	20%	15%	-	-
CO-4	20%	25%	30%	20%	20%	-	-
CO-5	20%	20%	30%	20%	25%	-	-
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) **Suggested Specification Table for End Semester Theory Assessment:** Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction to Geology	10	CO1	14	6	5	3
Unit-2.0 Minerology and Petrology	10	CO2	14	5	5	4
Unit-3.0 Rocks and Minerals	6	CO3	10	3	5	2
Unit-4.0 Geological Methods	12	CO4	18	3	8	7
Unit-5.0 Natural processes and Hazards	10	CO5	14	3	6	5
Total	**48**	**-**	**70**	**20**	**29**	**21**

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number (s)	PLA/ELA Performance PRA* (%)	PLA/ELA Performance PDA** (%)	PLA/ELA Viva-Voce (%)
1.	Determination of specific gravity of unknown material by steel yard's apparatus.	CO2	30	60	10
2.	Determination of specific gravity of feldspar by steel yard's apparatus.	CO2	30	60	10
3.	Determination of specific gravity of alumina by steel yard's apparatus.	CO2	30	60	10
4.	Determination of specific gravity of quartz by steel yard's apparatus.	CO2	30	60	10
5.	Determination of specific gravity of magnesite by steel yard's apparatus.	CO2	30	60	10
6.	Determination of the hardness of any unknown minerals.	CO2	30	60	10
7.	Identification of unknown mineral by physical properties.	CO2	30	60	10

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies:

Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S.No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/ PracticalNumber
1.	Steel yard's apparatus	Laboratory type	1,2,3,4,5
2.	Moh's scale box	Laboratory type	6,7
3.	Rock and Minerals Test Kit	Laboratory type	6,7
4.	Streak Plate	White Streak Plates, Size- 1*2 in.- 2*3 inch	6,7
5.	Petrological Microscope	Viewing Head: Monocular/Binocular/Trinocular Head 45°, 360° rotatable, Eyepiece: Eyepiece WF10X, Objective: Achromatic Objective 4X, 10X, 40X	7
6.	Electronic Balance	Range- 10 gm to 1000 gm.	1,2,3,4,5

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Introduction of Physical Geology	A.K. Datta	Kalyani Publishers ISBN-10: 8176637904
2.	A Textbook of Geology	P. K. Mukerjee	World Press Private Ltd Publisher, ISBN: 9788187567547
3.	Introduction To Geology	Dr. Vinod Agrawal	Raghav Publication ASIN : BOBXT26V6Q
4.	Engineering & General Geology	Parbin Singh	S.K. Kataria & Sons ISBN: 9789350142677

(b) Online Educational Resources:

1. https://en.wikipedia.org/wiki/Geology
2. https://archive.nptel.ac.in/courses/105/105/105105106/
3. https://en.wikipedia.org/wiki/Mineralogy
4. https://en.wikipedia.org/wiki/Petrology

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

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A) Course Code : **2413402(T2413402/P2413402/S2413402)**

B) Course Title : Chemistry for Ceramic Engineering

C) Pre- requisite Course(s) :

D) Rationale :

Diploma engineers have to deal with various chemicals in diverse technical and engineering field. Ceramic materials may be crystalline or partly crystalline. They are formed by the action of heat and subsequent cooling. Clay was one of the earliest materials used to produce ceramics, as pottery, but many different ceramic materials are now used in domestic, industrial, and building products. Ceramic materials tend to be strong, stiff, brittle, chemically inert, and non-conductors of heat and electricity, but their properties vary widely. For example, porcelain is widely used to make electrical insulators.

E) Course Outcomes (COs): After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

CO-1: Apply the properties and governing laws of gases for different practical applications.
CO-2: Analyze the effect of various physical factors on equilibrium of a chemical reaction.
CO-3: Apply the chemical kinetics concept to determine the order, molecularity, and half- life period of reactions.
CO-4: Apply the concepts of phase rule to determine different phases of component and properties affecting the Phase of system.
CO-5: Analyze processes associated with some important chemical compounds viz. Cupper Copper Sulphate, Gypsum, Plaster of Paris, Potassium Dichromate, Potassium Permanganate.

F) Suggested Course Articulation Matrix (CAM):

<table>
<tr><th rowspan="2">Course Outcomes (COs)</th><th colspan="7">Programme Outcomes (POs)</th><th colspan="2">Programme Specific Outcomes* (PSOs)</th></tr>
<tr><th>PO-1 Basic and Discipline Specific Knowledge</th><th>PO-2 Problem Analysis</th><th>PO-3 Design/ Development of Solutions</th><th>PO-4 Engineering Tools</th><th>PO-5 Engineering Practices for Society, Sustainability and Environment</th><th>PO-6 Project Management</th><th>PO-7 Lifelong Learning</th><th>PSO-1</th><th>PSO-2</th></tr>
<tr><td>CO-1</td><td>3</td><td>2</td><td>2</td><td>-</td><td>-</td><td>-</td><td>1</td><td></td><td></td></tr>
<tr><td>CO-2</td><td>3</td><td>2</td><td>1</td><td>2</td><td>2</td><td>1</td><td>2</td><td></td><td></td></tr>
<tr><td>CO-3</td><td>3</td><td>2</td><td>2</td><td>2</td><td>-</td><td>-</td><td>1</td><td></td><td></td></tr>
<tr><td>CO-4</td><td>3</td><td>1</td><td>1</td><td>-</td><td>1</td><td>-</td><td>1</td><td></td><td></td></tr>
<tr><td>CO-5</td><td>3</td><td>2</td><td>2</td><td>-</td><td>2</td><td>2</td><td>2</td><td></td><td></td></tr>
</table>

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G) Teaching & Learning Scheme:

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		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2413402	Chemistry for Ceramic Engineering	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

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TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2413402	Chemistry for Ceramic Engineering	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar, and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2413402

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. List the differences between states of matter. *TSO 1b.* Explain fundamental laws of gases. *TSO 1c.* Differentiate between ideal and real gas/ *TSO 1d.* State Raoult's law. *TSO 1e.* Describe colligative properties. *TSO 1f.* Determine surface tension by stalagmometer. *TSO 1g.* Determine viscosity by viscometer.	**Unit-1.0 States of Matter** 1.1 General Introduction– Comparison of the characteristics of solid, liquid and gases. 1.2 Gas Laws – Boyle's Law, Charles' Law, Avogadro Law, Ideal Gas Equation, Universal Gas Constant. 1.3 Kinetic Theory of Gases, Ideal and Real Gas 1.4 Solution- Solute, solvent, Raoult's law, Colligative properties. 1.5 Surface tension and viscosity and their determination.	**CO1**
TSO 2a. Differentiate between reversible and irreversible reactions. *TSO 2b.* Explain the law of mass action. *TSO 2c.* Derive relation between KP and KC. *TSO 2d.* Explain the effect of temperature, pressure, and concentration on chemical equilibrium. *TSO 2e.* Explain Lewis acids and bases. *TSO 2f.* Calculate the pH and pOH of solutions	**Unit-2.0 Chemical Equilibrium** 2.1 Introduction – Equilibria in chemical processes, reversible reaction, irreversible reaction, Concept of chemical equilibrium, Dynamic nature of chemical equilibrium. 2.2 Characteristics of chemical equilibrium, Law of mass action, Relation between KP and KC. 2.3 Factors affecting equilibrium, Le-Chatelier's Principle, Effect of change in concentration, pressure, and temperature on equilibrium. 2.4 Concepts of acids and bases (Bronsted-Lowry and Lewis Concept), Ionic product of water 2.5 Hydrogen ion concentration, pH scale, Simple numerical problems on pH and pOH	**CO2**
TSO 3a. Classify chemical reactions based on rate constant. *TSO 3b.* Determine the rate of reaction. *TSO 3c.* Distinguish between order and molecularity of reaction. *TSO 3d.* Write rate expression for first order reaction. *TSO 3e.* Calculate half-life period. *TSO 3f.* Calculate activation energy. *TSO 3g.* Explain the effect of temperature on rate constant.	**Unit-3.0 Chemical Kinetics** 3.1 General Introduction, Classification of reaction on the basis of Rate. 3.2 Rate of reaction, Order of reaction, Molecularity of a reaction: Zero order, First order, Second order reactions. 3.3 Derivation of rate constant for zero, first, and second order reactions. 3.4 Half-life period of a reaction, Units of Rate constant. 3.5 Effect of Temperature on Rate constant (Arrhenius equation)	**CO3**
TSO 4a. Describe phase, component, and degree of freedom. *TSO 4b.* Derive Gibbs' Phase Rule. *TSO 4c.* Draw the phase diagram of one component system. *TSO 4d.* Draw the phase diagram of two component system.	**Unit-4.0 Phase Rule** 4.1 Introduction, Definition of Phase, Component and Degree of Freedom. 4.2 Gibbs' Phase Rule and their derivation. 4.3 Phase diagram of One Component System e.g., Water and Sulphur System with phase diagram 4.4 Phase diagram of two component system	**CO4**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 5a. List physical properties of given metals. *TSO 5b.* List chemical properties of given metals. *TSO 5c.* Synthesize the given chemicals in the lab. *TSO 5d.* Explain the uses of given chemicals in ceramic industry.	**Unit-5.0 Chemical Compounds used in Ceramic Industries** 5.1 Preparation, properties, reactions and uses of Sodium Carbonate, Barium Carbonate, Calcium Carbonate 5.2 Copper Sulphate, Calcium Sulphate, Ferrous Sulphate 5.3 Gypsum, Plaster of Paris, Borax, Zinc Oxide, Aluminum Oxide, Lead Chloride, Silicon Carbide 5.4 Sodium Thiosulphate, Potassium Chromate, Potassium Dichromate, Potassium Permanganate	**CO5**

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2413402

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Determine the Viscosity of a liquid.	1.	Determination of Viscosity of a liquid using the Ostwald's Viscometer.	CO1
LSO 2.1. Determine surface tension.	2.	Determination of surface tension of benzene by the help of stalagmometer	CO1
LSO 3.1. Calculate pH. *LSO 3.2.* Observe the variation in pH of acid/base with dilution.	3.	Observation of variation in pH of acid/base with dilution.	CO2
LSO 4.1. Calculate pH.	4.	Determine pH of given solution by pH meter.	CO2
LSO 5.1. Determine the rate constant.	5.	Determination of rate constant of ester catalyzed by an acid at room temperature.	CO3
LSO 6.1. Draw cooling curve. *LSO 6.2.* Determine melting point using curve.	6.	Drawing of the cooling curve of benzoic acid and determination of its melting point.	CO4
LSO 7.1. Draw cooling curves. *LSO 7.2.* Determine eutectic temperature using curve.	7.	Drawing of cooling curve for benzoic acid and naphthalene mixture and determination of eutectic temperature.	CO4
LSO 8.1. Calculate amount of $KmnO_4$ required. *LSO 8.2.* Prepare N/10 $KmnO_4$ solution.	8.	Preparation of 250 ml of N/10 $KmnO_4$ Solution	CO5
LSO-9.1. Calculate amount of Potassium Dichromate required. *LSO-9.2.* Prepare N/10 Potassium Dichromate Solution.	9.	Preparation of 250ml of N/10 $K_2Cr_2O_7$ Solution	CO5
LSO 10.1. Calculate amount of Sodium Thiosulphate required.	10.	Preparation of N/10 Sodium Thiosulphate solution	CO5
LSO 11.1. Perform Iodometric titration.	11.	Standardization of approx. N/10 Sodium Thiosulphate solution with standard $KmnO_4$ Solution	CO5
LSO-12.1. Calculate amount of Copper Chloride required. LSO-12.2. Prepare Copper Sulphate	12.	Preparation of Copper Sulphate from Copper Chloride	CO5

L) **Suggested Term Work and Self Learning: S2413402** Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs such as -

1. Compare the pH value of different acids and bases.
2. Compare the oxidizing properties of Potassium Dichromate & Potassium Permanganate.
3. Prepare chart showing different industrial application of Sodium Carbonate, Barium Carbonate, Calcium Carbonate, Copper Sulphate, Calcium Sulphate, Ferrous Sulphate, Gypsum, Plaster of Paris, Borax, Zinc Oxide, Aluminum Oxide, Lead Chloride, Silicon Carbide, Sodium Thiosulphate, Potassium Chromate, Potassium Dichromate, Potassium Permanganate.
4. Calculate the number of phases, degree of freedom for one and two component system respectively.
5. Apply the concept of phase rule in separation of different component of a petroleum using phase diagram of two component system.
6. Calculate Kp and Kc for given chemical reactions.

b. Micro Projects:

1. Compare the pH of a given acidic and basic solution.
2. Compare between zero order and first order reaction.
3. Determine the Phase, Component and Degree of Freedom in decomposition of Calcium Carbonate.
4. Collect water from different sources and compare their pH and pOH.

c. Other Activities:

1. Seminar Topics:
   - Ionic product of water.
   - Compare the Viscosity of different liquids.
   - Properties of ideal and real gases.
   - Application of Le-Chatelier's Principle
2. Visits:
   - Visit nearby chemical industry. Prepare report of visit.
   - Visit nearby tiles showroom. Prepare report of visit
3. Self-Learning Topics:
   - Kinetic theory of gases.
   - Le-Chatelier principle
   - Graphs of different order reactions
   - Application of phase rule and phase diagram
   - Some important inorganic and organic chemicals used in ceramic industry.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	20%	20%	15%	-	-	20%	-
CO-2	20%	20%	10%	25%	-	20%	25%
CO-3	20%	20%	15%	25%	33%	15%	25%
CO-4	15%	15%	30%	25%	33%	15%	25%
CO-5	25%	25%	30%	25%	34%	30%	25%
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 States of Matter	11	CO1	14	4	4	6
Unit-2.0 Chemical Equilibrium	10	CO2	14	4	4	6
Unit-3.0 Chemical Kinetics	11	CO3	14	4	4	6
Unit-4.0 Phase Rule	8	CO4	11	4	4	3
Unit-5.0 Chemical Compounds used in Ceramic Industries	8	CO5	17	4	7	6
Total	**48**	**-**	**70**	**20**	**23**	**27**

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number(s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Determination of Viscosity of a liquid using the Ostwalds's Viscometer.	CO1	30	60	10
2.	Determination of surface tension of benzene by the help of stalagmometer	CO1	40	50	10
3.	Observation of variation in pH of acid/base with dilution.	CO2	30	60	10
4.	Determine pH of given solution by pH meter.	CO2	30	60	10
5.	Determination of rate constant of ester catalyzed by an acid at room temperature.	CO3	30	60	10
6.	Drawing of the cooling curve of benzoic acid and determination of its melting point.	CO4	30	60	10
7.	Drawing of cooling curve for benzoic acid and naphthalene mixture and determination of eutectic temperature.	CO4	30	60	10
8.	Preparation of 250 ml of N/10 $KmnO_4$ Solution	CO5	40	50	10
9.	Preparation of 250ml of N/10 $K_2Cr_2O_7$ Solution	CO5	40	50	10
10.	Preparation of N/10 Sodium Thiosulphate solution	CO5	40	50	10
11.	Standardization of approx. N/10 Sodium Thiosulphate solution with standard $KmnO_4$ Solution	CO5	30	60	10
12.	Preparation of Copper Sulphate from Copper Chloride	CO5	30	60	10

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

Note: This table can be used for both end semesters as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/Practical Number
1.	pH Meter	Type: Microcontroller Based, Display: LED / LCD / Touch Screen, 3 digits, Calibration: up to 3 points with auto buffer, pH Range (pH): 0.00 to 14.00, +/- 0.05, Power Requirements: 230 V +/- 10, 50 Hz AC, Modes: pH mV- C, Temperature Compensation Type: Automatic, Temperature Compensation Range (Degree C): 0 to 100, Temperature Accuracy (Degree C): +/- 0.3, Resolution (pH): 0.01	3,4
2.	Ostwald Viscometer	Size 120x1 mm (length x internal diameter) Overall, Height 237 nm Material- Glass	1
3.	Stalagmometer	Size 2.5 mL Material- Glass	2
4.	Electronic balance,	Scale range of 0.001g to 500g. Pan size 100 mm; response time 3-5 sec.; power requirement 90-250 V, 10 watt.	8-12

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Engineering Chemistry	Jain & Jain	Dhanpat Rai Publishing Co.(P) Ltd., New Delhi, 2015, ISBN: 93-521-6000-2
2.	A Textbook of Engineering Chemistry	Dr S. S. Dara & Dr S. S. Umare	S. Chand & Co.(P) Ltd., New Delhi, 2014, ISBN:81-219-0359-9
3.	Textbook of Chemistry for Class XI & XII (Part-I & II)	NCERT	NCERT, New Delhi, 2017-18, Class-XI, ISBN: 81-7450-494-X (part-I), 81-7450-535-O (part-II), Class-XII, ISBN: 81-7450-648-9 (part-I), 81-7450-716-7 (part-II)
4.	Engineering Chemistry	Shikha Agarwal	Cambridge Uni. Press, New Delhi, 2019, ISBN: 978-1-108-72444-9
5	Engineering Chemistry	Dr. Vikram, S.	Wiley India Pvt. Ltd., New Delhi, 2013, ISBN: 9788126543342
6	Chemistry for Engineers	Rajesh Agnihotri	Wiley India Pvt. Ltd., 2014, ISBN: 9788126550784
7	Physical Chemistry	Puri, Sharma, and Pathania	Vishal Publication,2020, ISBN:978-9382956013

(b) Online Educational Resources:

1. https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Physical_Properties_of_Matter/States_of_Matter/Properties_of_Gases/Gas_Laws/Gas_Laws%3A_Overview
2. https://www.khanacademy.org/science/chemistry/chem-kinetics
3. https://www.khanacademy.org/science/chemistry/chemical-equilibrium
4. https://www.khanacademy.org/test-prep/mcat/chemical-processes/acid-base-equilibria/v/acid-base-definitions-1
5. https://www.khanacademy.org/test-prep/mcat/chemical-processes/acid-base-equilibria/v/definition-of-ph
6. https://www.khanacademy.org/test-prep/mcat/chemical-processes/acid-base-equilibria/v/autoionization-of-water
7. https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces/states-of-matter/v/phase-diagrams

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

(c) Others:

1. Learning Packages.
2. Lab Manuals.
3. Manufacturers' Manual
4. Users' Guide Lab Manuals

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A) **Course Code** : **2413403(T2413403/P2413403/S2413403)**

B) **Course Title** : Ceramic Processing

C) **Pre- requisite Course(s)** :

D) **Rationale** :

Ceramic Graduates work in various industries for product development and application. Ceramic processing course introduces students to the fundamental principles and techniques of various ceramic processing operations in the ceramic processing industry. It covers the basic principles of material handling, size reduction, mixing, shaping, drying, firing, and finishing in the context of ceramic materials. The course emphasizes the practical applications in the ceramic industry.

E) **Course Outcomes (COs):** After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

CO-1 Utilize theory to address industrial ceramic processing and material selection issues.

CO-2 Apply theoretical knowledge of processing additives in practical scenarios, formulating ceramic materials with desired properties.

CO-3 Choose acceptable compaction methods for ceramic products.

CO-4 Compare size reduction and separation methods and equipment to separate heterogeneous mixtures.

CO-5 Choose a suitable firing method based on product requirements.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	**PO-2** Problem Analysis	**PO-3** Design/ Development Solutions	**PO-4** Engineering Tools	**PO-5** Engineering Practices for Society, Sustainability and Environment	**PO-6** Project Management	**PO-7** Life Long Learning	**PSO-1**	**PSO-2**
CO-1	3	-	-	2	-	-	2		
CO-2	3	2	2	-	-	-	-		
CO-3	3	2	-	2	2	-	-		
CO-4	3	1	2	2	-	2	2		
CO-5	3	2	-	1	-	-	1		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2413403	Ceramic processing	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

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2413403	Ceramic processing	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

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Note:

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I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2413403

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain the historical evolution and development of ceramic processing. *TSO 1b.* Differentiate between traditional ceramics and advanced ceramics. *TSO 1c.* Explain the importance of industrial ceramic processing in different industries. *TSO 1d.* Differentiate between wetting and non-wetting characteristics of liquids on ceramic surfaces. *TSO 1e.* Explain the principles of surface chemistry and its influence on wetting behavior in ceramic processing. *TSO 1f.* List material characterization techniques such as particle, powder, colloidal, and agglomeration analysis. *TSO 1g.* Explain bulk chemical analysis and XRF. *TSO 1h.* Explain mean particle size, particle size distribution, and their relevance in ceramic powders.	**Unit-1.0 Introduction to Ceramic Processing** 1.1 Introduction: -History of ceramic processing, traditional ceramics, Advanced ceramics, industrial ceramic processing, science in ceramic processing 1.2 Surface chemistry: - wetting and non-wetting characteristics of liquid 1.3 Material characterization: -particles, powders, collides, agglomerates. 1.4 Chemical and phase composition: -Bulk chemical analysis, XRF 1.5 Particle size and shape: -Mean particle size, particle size distribution.	**CO1**
TSO 2a. Explain liquid suspension particle charging and electrical double layer. *TSO 2b.* Explain the properties of different liquids and their relevance in industries. *TSO 2c.* Describe ceramic suspension stability deflocculants and coagulants. *TSO 2d.* Differentiate between clay, molecular binders, resins, and hydraulic cement. *TSO 2e.* Explain the functions of ceramic processing additives, including plasticizers, foaming agents, anti-forming agents, lubricants, and preservatives.	**Unit-2.0 Processing Additives** 2.1 Liquids and wetting Agents: -Water, organic liquid, Polar liquid. 2.2 Deflocculants and coagulants: -Particle charging in liquid suspension, Electrical double layer, Deflocculation, suspension stability, coagulation, and flocculation. 2.3 Flocculants, Binders, and Bonds: Types of binders, clay binders, molecular binders, resins, and hydraulic cement. 2.4 Plasticizers, foaming and antifarming agents, Lubricants, and Preservatives.	**CO2**
TSO 3a. Explain the characteristics of packing uniform spheres, packing in voids, and multimodal packing. *TSO 3b.* Explain the pressing principles, including dry pressing, powder flow, compaction behavior, die wall effects, and various compaction methods such as isostatic compaction and roll pressing. *TSO 3c.* Describe plastic forming processes such as extrusion, jiggering, and	**Unit-3.0 Densification and Forming** 3.1 Characteristics of packing of uniforms sphere, packing in void, multi-model 3.2 Pressing: dry pressing, powder flow and die filling, compaction behavior, die wall effects, isostatic compaction, roll pressing 3.3 Plastic forming: -extrusion process, extrusion machine, extrusion defects and control, jiggering, injection, moulding process injection, moulding equipment, injection moulding defects and control	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
injection molding, along with defects and control mechanisms. *TSO 3d.* Describe the steps involved in slip preparation. *TSO 3e.* Explain the advanced techniques such as pressure casting, vacuum casting, and centrifugal casting. *TSO 3f.* Explain the vapor deposition process and its applications in ceramic processing.	3.4 Slip casting: -slip preparation, slip casting, particles and mechanics, pressure casting, vacuum casting, centrifugal casting, porous mould materials, slip casting problems and controls, tap casting process 3.5 Vapor Deposition	
TSO 4a. Explain the concept of size reduction and Rittinger's law. *TSO 4b.* Describe various size reduction equipment such as crushers, grinders, and hammer mills. *TSO 4c.* Explain the principles of separation. *TSO 4d.* Explain the concept of mixing and different mixing equipment, including paddle stirrers, propellers, kneaders, and dry mixers. *TSO 4e.* Explain different conveying equipment and their primary mechanism. *TSO 4f.* Explain the filtration concept and its importance in separating solids from liquids.	**Unit-4.0 Size reduction, Separation , Mixing, and Converging Techniques** 4.1 Size reduction: Introduction, Rittenger's law, crusher, jaw crusher, gyratory crusher, cone crusher, grinder, hammer mill, rolling compression mill, attrition mill, ball mill, rod mill, tube mill, ultra fine grinder, cutting machine 4.2 Separation: concept of separation, heterogeneous mixture (solid from gas, liquid from gas, solid from solid), concept of screening, types of screen equipment, grizzlies, trommels, shaking screen, vibrating screen, cyclone separator 4.3 Mixing: Concept of mixing, paddle stirrer, propeller, kneader, dry mixer, and muller mixer 4.4 Conveying: belt- conveyer, or strictions and operation, chain conveyer, screw conveyer, bucket elevator 4.5 Filtration: the concept of filtration, filter press constructions and function.	**CO4**
TSO 5a. Explain the concept of drying. *TSO 5b.* Differentiate between batch dryers, compartment dryers, tunnel dryers, and conveyer dryers. *TSO 5c.* Explain the importance and function of firing in ceramic processing. *TSO 5d.* Differentiate between continuous and batch-type kilns. *TSO 5e.* Describe the construction and operation of different types of kilns,	**Unit-5.0 Drying and Firing** 5.1 Concept of drying, classification of dryers, batch dryers, compartment dryers, continuous dryers, tunnel dryers, conveyer dryers, drum dryers, spray dryers 5.2 Function of firing, firing equipment, continuous type, and batch type kiln construction and operation, updraft kiln, down draft kiln, tunnel kiln, electric kiln.	**CO5**

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2413403

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs Number(s)
LSO 1.1. Conduct sieve analysis. *LSO 1.2.* Determine the particle size distribution of the milled product.	1.	• Performing Sieve analysis on the milled product.	CO1, CO4
LSO 2.1. Demonstrate the procedure for setting up and calibrating the jaw crusher for the experiment. *LSO 2.2.* Conduct experiments to crush the sample material using the jaw crusher, systematically varying the feed size and crusher settings. *LSO 2.3.* Calculate the crushing efficiency of the jaw crusher.	2.	• Determination of crushing efficiency of a Jaw Crusher.	CO4
LSO 3.1. List the equipment and materials required for the experiment, including the ball mill, grinding media, sample material, scales, and safety equipment. *LSO 3.2.* Determine the critical speed of the ball mill by varying the ball mill's rotational speed systematically. *LSO 3.3.* Calculate the critical rotational speed of the ball mill using the experimentally obtained data.	3.	• Determination of critical speed and crushing rate of a Ball Mill.	CO4
LSO 4.1. List the equipment and materials required for the experiment, including a filtration setup, ceramic slurry sample, filter media, vacuum pump, and measuring instruments. *LSO 4.2.* Analyze the filtration rate data.	4.	• Determination of filtration rate of ceramic slurry.	CO2, CO3, CO4
LSO 5.1. List the materials and equipment required for preparing slurry, including raw ceramic powders, water, deflocculants, mixing equipment, and safety gear. *LSO 5.2.* Demonstrate techniques for accurately weighing and measuring raw materials, ensuring precise formulation and consistency in slurry composition.	5.	• Preparation of slurry for slip casting of oxide ceramics	CO3, CO4
LSO-6.1. List the essential materials and equipment required for shaping POP molds, including plaster of Paris, water, mixing tools, release agents, model or pattern, and safety gear. *LSO-6.2.* Choose an appropriate model or pattern for the mold, ensuring it is clean and free from imperfections.	6.	• Preparation of mould using plaster of Paris.	CO3, CO4
LSO-7.1. Recognize safety features and emergency controls incorporated into hydraulic presses.	7.	• Operation of Hydraulic Press.	CO3, CO4

L) Suggested Term Work and Self-Learning: S2413403 Some sample suggested assignments, micro-projects, and other activities are referenced here.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

1. Explore the historical development of ceramic processing techniques, from ancient pottery to modern industrial applications, and prepare a present in the class.
2. Investigate the criteria and considerations for selecting raw materials in ceramic processing, including clays, feldspars, and other components, and prepare a report.
3. Write a detailed report on types of binders, focusing on clay, molecular binders, resins, and hydraulic cement.
4. Compare and contrast the characteristics of packing uniform spheres, packing in void, and multi-model packing and prepare a report.
5. Explore the applications and the advantages of each packing method in various industries and present them in the class
6. Explore various plastic forming techniques such as extrusion, injection molding, and jiggering.
7. Collect pictures of different size reduction equipment and represent them in the class.

b. Micro Projects:

1. Identify the critical processing parameters that can be optimized, such as sintering temperature, time, compaction pressure, and raw material composition, and prepare a report.
2. Characterize the particle size reduction process and prepare a report.
3. Prepare samples of different particle sizes and shapes, then employ appropriate characterization methods to analyze them and prepare a report including images and data.
4. Conduct experiments to measure the contact angles of ceramic slurries with water, organic liquid, and polar liquid, and prepare a report to understand the wetting properties and implications for processing.
5. Design and prototype a ceramic product using plastic forming techniques (extrusion or injection molding) and compare the quality and efficiency of the products produced through different forming methods and prepare a report.

c. Other Activities:

1. Seminar Topics:
   - Advanced Techniques in Ceramic Sintering: Enhancing Properties and Performance
   - Ceramic Nanocomposites: Synthesis, Characterization, and Applications
   - Green Ceramics: Sustainable Processing and Eco-Friendly Materials
   - Optimization of Separation Processes: Techniques and Applications
   - Fundamentals of Ceramic Processing: From Raw Materials to Final Products

2. Visits: Visit nearby ceramic industry, and prepare a report of visit with special comments of material used for bricks manufacturing, process applied, major application area, major consumer, costing.

3. Self-Learning Topics:
   - Ceramic Coatings for High-Temperature Applications.
   - Advanced Mixing Technologies for Process Unit Operations.
   - Ceramic Matrix Composites.
   - Ceramic Materials for Biomedical Engineering.
   - Ceramic Processing in Electronics.

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	20%	20%	20%	15%	15%	**10%**	10%
CO-2	15%	15%	10%	20%	15%	**15%**	15%
CO-3	20%	20%	25%	20%	25%	**40%**	40%
CO-4	30%	30%	25%	20%	25%	**35%**	35%
CO-5	15%	15%	20%	25%	20%	**-**	-
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction to Ceramic Processing	10	CO1	14	5	6	3
Unit-2.0 Processing Additives	7	CO2	10	4	4	2
Unit-3.0 Densification and Forming	10	CO3	15	5	7	3
Unit-4.0 Size Reduction, Separation, Mixing and Converging Techniques	14	CO4	21	4	10	7
Unit-5.0 Drying and Firing	7	CO5	10	2	5	3
Total	**48**	**-**	**70**	**20**	**32**	**18**

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number (s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Sieve analysis and particle size distribution of milled product.	CO1, CO4	30	60	10
2.	Verification of Rittinger's Crushing Law and determination of crushing efficiency of a Jaw Crusher.	CO4	40	50	10
3.	Determination of critical speed and crushing rate of a Ball Mill.	CO4	30	60	10
4.	Determination of filtration rate of ceramic slurry.	CO3, CO4	30	60	10
5.	Preparation of slurry for slip casting of oxide ceramics.	CO2, CO3, CO4	30	60	10
6.	Preparation of mould using plaster of paris.	CO3, CO4	30	60	10
7.	Operation of Hydraulic Press.	CO3, CO4	30	60	10

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

Note: This table can be used for both end semester and progressive assessment of practical. Rubrics need to beprepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S. No.	Name of Equipment,Tools and Software	Broad Specifications	Relevant Experiment /Practical Number
1.	Set of Sieves	Capacity- 2 kg, Measurement range from 5 µm to 63 mm,	1
2.	Vibration table	Laboratory Type, volt -220	1
3.	Jaw Crusher	Laboratory Type, High crushing efficiency, feed sizes up to 40 mm can be crushed to 0.5 mm, Removable jaw for easy cleaning, Adjustable speed, Wear compensation with zero-point adjustment, Convenient operating keypad with digital display, Memory for gap width setting. Capacity- 100-200 kg/hours, 440 volts, 3 phase	1,2
4.	Ball Mill	Laboratory Type, Max. speed 650 rpm Up to 10 mm feed size and 0.1 µm final fineness 1 grinding station for jars from 12 ml up to 500 ml Jars of 12 – 80 ml can be stacked (two jars each) Grind Control to measure temperature and pressure inside the jar. Aeriation lids to control the atmosphere inside the jar. Storable SOPs and cycle programs, 5 different jar materials for dry and wet grinding Capacity- 5 to 10 kg, Rotation speed- 30-80 rpm,2 HP, 220 volt	1,3
5.	Filter press	Laboratory Type	3
6.	Hydraulic Press	Laboratory Type	7

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Principles of Ceramics Processing	James S. Reed	Wiley-Interscience Publisher ISBN: 9780471597216
2.	Ceramic Processing and Sintering	M. N. Rahman	CRC Press ISBN: 9781498797832
3.	Unit Operation of Chemical Engineering	J. C. Smith	McGraw Hill, ISBN: 9780072848236

(b) Online Educational Resources:

1. https://ceramicartsnetwork.org/
2. https://digitalfire.com/
3. https://en.wikipedia.org/wiki/Ceramic_forming_techniques
4. https://en.wikipedia.org/wiki/Ceramic_mold_casting
5. https://en.wikipedia.org/wiki/Unit_operation
6. https://simple.wikipedia.org/wiki/Ceramic_sintering

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

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A) Course Code : **2413404(T2413404/P2413404/S2413404)**

B) Course Title : Pottery and Porcelain Technology

C) Pre- requisite Course(s) : Ceramic Raw materials

D) Rationale :

The Pottery and Porcelain Technology course is designed to provide students with a comprehensive understanding of the processes, materials, and techniques involved in pottery and porcelain production. Students will gain both the theoretical principles and practical skills necessary for successful ceramic production. The Pottery and Porcelain Technology specialty combines technical skills, creative flair, and commercial savvy. This course prepares graduates for successful and rewarding ceramics professions by providing a thorough grasp of pottery and porcelain manufacturing techniques, historical background, and current trends. Students will be prepared to contribute to the booming ceramic and porcelain manufacturing industry, satisfying market and cultural heritage needs via theoretical knowledge and hands-on practice.

E) Course Outcomes (COs): After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

CO-1 Apply the knowledge of ceramic colors to create various glazes and decorative elements, demonstrating artistic and technical proficiency in color selection and combination.

CO-2 Prepare ceramic body compositions using various raw materials and their proportions for different products.

CO-3 Apply glazes to ceramic surfaces using various methods for uniform coverage and desired visual effects.

CO-4 Choose the appropriate drying and firing technique to dry and fire ceramic items without flaws.

CO-5 Produce high-quality ceramics by minimizing glazing, drying, and fire flaws.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)	
	PO-1 Basic and Discipline Specific Knowledge	**PO-2** Problem Analysis	**PO-3** Design/ Development Solutions	**PO-4** Engineering Tools	**PO-5** Engineering Practices for Society, Sustainability and Environment	**PO-6** Project Management	**PO-7** Life Long Learning	**PSO-1**	**PSO-2**
CO-1	3	-	-	-	-	-	2		
CO-2	3	2	1	1	-	2	-		
CO-3	3	2	2	2	2	-	-		
CO-4	3	2	2	2	1	-	1		
CO-5	3	2	2	2	1	-	2		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2413404	Pottery and Porcelain Technology	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2413404	Pottery and Porcelain Technology	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in class room (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar, and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2413404

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain pottery and its historical Significance. *TSO 1b.* Describe naturally occurring raw materials such as clay, quartz, feldspar, and other minerals used in pottery production. *TSO 1c.* Explain the significance of synthetic raw materials. *TSO 1d.* Differentiate earthenware, terracotta, stoneware, porcelainware, and bone china. *TSO 1e.* Explain the role of various ceramic colours in pottery and porcelain production.	**Unit-1.0 Introduction to Pottery** 1.1 Definition, History of Pottery. 1.2 Raw Materials, Naturally Occurring Raw Materials: Clay, Quartz, Feldspar, Nepheline Syenite, Talc, Pyrophyllite, Wollastonite, Sillimanite, Kyanite, Andalusite, Zircon, Bone Ash, Gypsum, 1.3 Synthetic Raw Material: Alumina, Zirconia, Beryllia. 1.4 Classification: Earthenware, Terracotta, Stoneware, Porcelain Ware, Bone China. 1.5 Ceramic Colours: Cr_2O_3, CaO, Fe_2O_3, TiO_2, V_2O_5 and its combination.	**CO1**
TSO 2a. Explain raw material transit, unloading, storage, batch computation, batching, and body composition preparation. *TSO 2b.* Explain the principles of slip and solid casting. *TSO 2c.* Apply slip and solid casting techniques to create ceramic products. *TSO 2d.* Explain the applications and limitations of Throwing, Jiggering, Jollying, Extrusion, Turning, and Injection Moulding. *TSO 2e.* Apply various plastic forming techniques based on the requirement of ceramic product. *TSO 2f.* Explain the role of binders and lubricants in pressing processes. *TSO 2g.* Explain the specific properties and manufacturing requirements of different ceramic products.	**Unit-2.0 Body Preparation, Forming, and Shaping** 2.1 Body Preparation: Transport of Raw Materials, Unloading and Storage of Raw Materials, Batch Calculation, Batching, Preparation of The Body Composition 2.2 Slip Casting, Preparation of Stable Slip, Mould for Slip Casting, Solid Casting 2.3 Plastic Forming Process, Throwing, Jiggering, Jollying, Extrusion, Turning, Injection Moulding 2.4 Pressing, Dry Pressing, Binders, Lubricants, Isostatic Pressing, Hot Pressing 2.5 Products: Wall tiles, floor tiles, sanitary ware, wash basin, Low- and High-tension insulators, Ferrite, Capacitor	**CO2**
TSO 3a. Explain Glaze and its role in ceramic production. *TSO 3b.* Classify glazes based on their composition and characteristics. *TSO 3c.* Explain opacifiers and their function in glaze formulation. *TSO 3d.* Apply criteria for selecting appropriate glazes for specific ceramic products. *TSO 3e.* Explain the purpose and significance of decoration in ceramics. *TSO 3f.* Differentiate between underglaze, in glaze, and onglaze decoration methods. *TSO 3g.* Identify the materials and tools used in ceramic decoration.	**Unit-3.0 Glazing and Decoration** 3.1 Glaze: Classification of Glaze, Opacifiers, Glaze Materials, Glaze Selection Criteria, Preparation of Glaze, Application of Glaze, Glaze Body Interaction 3.2 Decoration, Purpose of Decoration, Under Glaze Decoration, In Glaze Decoration, On Glaze Decoration, Ceramic Transfer Paper.	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 4a. Explain the function of the drying process in ceramic production. *TSO 4b.* Explain the factors that affect the drying of ceramic products. *TSO 4c.* Describe the different types of dryers used in ceramics, including chamber dryers and continuous dryers. *TSO 4d.* Explain the principles and procedures involved in drying ceramics effectively. *TSO 4e.* Describe the role of firing in ceramics and its importance in achieving specific product properties. *TSO 4f.* Differentiate between biscuit firing and glost firing. *TSO 4g.* Explain various types of kilns used in ceramic firing, such as chamber kilns, continuous kilns, tunnel kilns, and muffles kilns. *TSO 4h.* Explain the firing schedules and temperature profiles required for different types of ceramics.	**Unit-4.0 Drying and Firing** 4.1 Drying Function, Factors Affecting Drying, Types of Dryers, Chamber Dryer, Continuous Dryer. 4.2 Firing Function, Biscuit Firing, Glost Firing, Type of Kiln, Chamber Kiln, Continuous Kiln, Tunnel Kiln, Muffles Kiln, Saggars	**CO4**
TSO 5a. Explain common glaze defects, including blisters, pinholes, eggshells, waviness, crazing, and dullness. *TSO 5b.* Explain the causes and contributing factors leading to glaze defects. *TSO 5c.* Evaluate the impact of glaze defects on the visual and functional quality of ceramic products. *TSO 5d.* Recognize different methods for preventing or minimizing glaze defects. *TSO 5e.* Explain drying defects in ceramics, such as warpage and drying shrinkage. *TSO 5f.* Explain the reasons behind the occurrence of drying defects. *TSO 5g.* Explain firing defects like firing shrinkage and cracks in ceramic products. *TSO 5h.* Analyze the root causes and factors contributing to firing defects	**Unit-5.0 Defects and Remedies**. 5.1 Glaze Defect: Blisters, Pinholes, Eggshell, Waviness, Crazing, Dullness 5.2 Drying Defect: Warpage, Drying Shrinkage 5.3 Firing Defect: Firing Shrinkage, Cracks Composite, Titanium Diboride, Lithium Aluminosilicates	**CO5**

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2413404

Practical/Lab Session Outcomes (LSOs)	S. No.	Laboratory Experiment/Practical Titles	Relevant COs
LSO 1.1 Prepare a POP mold for slip casting, including Plaster of Paris, water, mixing containers, clay, release agents, and molds. *LSO 1.2* Prepare a Plaster of Paris mold, including Mixing ratios, smoothing the surface, and curing time. *LSO 1.3* Consider mold design, including undercuts, vents, and pour spouts for slip casting. *LSO 1.4* Offer remedies for frequent slip-casting issues.	1.	• Preparation of Plaster of Paris mould for Slip Casting.	CO1, CO2
LSO 2.1. Select the materials and tools required for slip preparation and forming a body. *LSO 2.2.* Create a slip, including measuring and mixing clay and water. *LSO 2.3.* Removing the cast piece from the mold.	2.	• Preparation of slip and form a body by Plaster of Paris mould.	CO1, CO2
LSO 3.1. Wedge, knead, and adjust clay consistency and moisture for jiggering and jollying. *LSO 3.2.* Propose solutions for common problems that may arise during jiggering and jollying. *LSO 3.3.* Refine the jiggered and jollied ware.	3.	• Preparation of ware by jiggering and jollying process.	CO1, CO2, CO4
LSO 4.1. Demonstrate wheel throwing for making clay shapes. *LSO 4.2.* Select the materials and tools necessary for wheel throwing. LSO 4.3. Use an electric pottery wheel to prepare ware.	4.	• Preparation of wares by method of rotating electrical wheels.	CO1, CO2 CO4
LSO 5.1. Select the materials and tools necessary for preparing a white ware body. *LSO 5.2.* Combine components to ensure equal particle distribution and minimize air bubbles.	5.	• Preparation of white ware body of given composition.	CO1, CO2, CO4
LSO-6.1. List the materials and tools necessary for preparing colored glazes and applying them to ceramic wares. *LSO-6.2.* Measuring glaze ingredients according to the recipe for accuracy and repeatability. *LSO-6.3.* Complete the desired surface finish using various glaze application techniques.	6.	• Preparation of coloured glaze and application on wares.	CO3, CO4, CO5
LSO-7.1. List the materials and tools needed for measuring drying and firing shrinkage. *LSO-7.2.* Calculate the drying shrinkage percentage.	7.	• Determine drying and firing shrinkage of a given sample.	CO4, CO5

L) Suggested Term Work and Self Learning: S2413404 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

- **a. Assignments**: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

1. Write a detailed essay on the historical significance of pottery in a specific ancient civilization.
2. Create a comprehensive chart listing the naturally occurring and synthetic raw materials used in pottery production including their properties and common applications.
3. Prepare a report on sustainable ceramic raw material sourcing.
4. Investigate common glaze defects, propose effective remedies for each defect and prepare a report.
5. Explore ceramic decorating ideas including ceramic transfer paper and digital printing. Assess these methods' environmental effects.
6. Explore ceramic decorating ideas including ceramic transfer paper and digital printing and assess these methods' environmental effects and present the findings in the class.

b. Micro Projects:

1. Visit a pottery workshop or factory and analyze ceramic raw material samples for texture, color, and content and prepare a report thoroughly.
2. Create a unique ceramic product using diverse raw materials and forming methods. Make a hand-built or thrown prototype. Document the whole process, including problems and solutions.
3. Compare Slip casting, plastic shaping (throwing, jiggering, jollying, extrusion, turning, and injection molding), and pressing and analyze each method's pros, cons, and applications.
4. Visit a Ceramic manufacturing facility and investigate the inefficiencies in body preparation and forming process and prepare a report.
5. Create a decorative ceramic piece and document the process, challenges faced, and the significance of the chosen decoration methods.

Other Activities:

1. Seminar Topics:
   - Commercially available pottery making raw materials in India.
   - Tiles export and import in India.
   - Major application areas of pottery.
   - Primary raw materials used in porcelain clay formulation, including kaolin, feldspar

2. Visits: Visit nearby industry of pottery manufacturing. Prepare a report of visit with special comments on the material used for pottery manufacturing, the process applied, major application area, major consumer, costing.

3. Self-Learning Topics:
   - Nanotechnology in the Pottery Industry
   - High tension insulator manufacturing and use
   - The role of particle size affects workability, plasticity, and firing results.
   - High tech products of porcelain.

M) **Suggested Course Evaluation Matrix:** The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		Term Work Assessment (TWA)			Lab Assessment (LA)#	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	End Theory Assessment (ETA)	Term Work & Self Learning Assessment			Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)
			Assignments	Micro Projects	Other Activities*		
CO-1	15%	15%	15%	15%	-	15%	20%
CO-2	30%	30%	30%	25%	-	25%	20%
CO-3	30%	30%	30%	25%	33%	25%	20%
CO-4	15%	15%	15%	25%	33%	15%	20%
CO-5	10%	10%	10%	10%	34%	20%	20%
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) **Suggested Specification Table for End Semester Theory Assessment:** Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction to Pottery	8	CO1	12	5	3	4
Unit-2.0 Body preparation, Forming and Shaping	13	CO2	19	5	5	9
Unit-3.0 Glazing and Decoration	13	CO3	19	5	5	9
Unit-4.0 Drying and Firing	7	CO4	10	3	3	4
Unit-5.0 Defects and Remedies	7	CO5	10	2	3	5
Total	**48**	**-**	**70**	**20**	**19**	**31**

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number (s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Preparation of Plaster of Paris mould for Slip Casting.	CO1, CO2	30	60	10
2.	Preparation of slip and form a body by Plaster of Paris mould.	CO1, CO2	40	50	10
3.	Preparation of ware by jiggering and jollying process.	CO1, CO2, CO4	30	60	10
4.	Preparation of wares by method of rotating electrical wheels.	CO1, CO2, CO4	30	60	10
5.	Preparation of white ware body of given composition.	CO1, CO2, CO4	30	60	10
6.	Preparation of colored glaze and application on wares.	CO3, CO4, CO5	30	60	10
7.	Determine the drying and firing shrinkage of a given sample.	CO4,CO5	30	60	10

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies:

Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools, and Software:

S. No.	Name of Equipment, Tools, and Software	Broad Specifications	Relevant Experiment/ PracticalNumber
1.	Electric Dryer	Temperature Range- 50-200 o C, Size-18’’*18’’*18’’	5,6,7
2.	Electric Furnace	Temperature Range- 1600 o C-2000 o C, Size of chamber – 18’’*18’’*18’’	5,6,7
3.	Laboratory Jaw Crusher	Laboratory Type, High crushing efficiency, feed sizes up to 40 mm can be crushed to 0.5 mm, Removable jaw for easy cleaning, Adjustable speed, Wear compensation with zero-point adjustment, Convenient operating keypad with digital display, Memory for gap width setting. Capacity- 100-200 kg/hours, 440 volts, 3 phase	5,6
4.	Laboratory Ball Mill with porcelain balls	Laboratory Type, Max. speed 650 rpm, Up to 10 mm feed size and 0.1 µm final, fineness 1 grinding station for jars from 12 ml up to 500 ml Jars of 12 – 80 ml can be stacked (two jars each) Grind Control to measure. Temperature and pressure inside the jar. Aeration lids to control the atmosphere inside The jar. Storable SOPs and cycle programs, 5 different jar materials for dry and wet grinding, Capacity- 5 to 10 kg, Rotation speed- 30-80 rpm,2HP, 220 volt	5,6
5.	Weighing balance	Digital type, Range- 10 gm to 10 kg	1,2,4,5,6,
6.	Electrical operated potter wheel	Size- 30 cm, volt- 220, single phase	4
7.	Porcelain crucible	Capacity -200-500 gm.	6

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Ceramic Materials Formation	R. P. Sinha	Novelty; 2nd Edition, ASIN: B083W91KDL
2.	Ceramic White Wares	Sudhir Sen	Oxford & IBH Publishing Co., New Delhi, ISBN 8120406753, 9788120406759
3.	A Handbook of Modern Pottery Manufacture	H. N. Bose	Ceramic Publishing House, India ISBN: 223744655
4.	Ceramic glazes	Kenneth Shaw	Publisher: Elsevier Science Ltd, ISBN-10 : 0444201076
5.	Element of Ceramic	F. H. Norton	Publisher: Longman Higher Education; 2nd edition, ISBN-10 : 0201053063
6.	Industrial Ceramic	Singer and Singer	Publisher: Springer, ISBN-10 : 9401752591

(b) Online Educational Resources:

1. https://en.wikipedia.org/wiki/Pottery
2. https://en.wikipedia.org/wiki/Porcelain
3. https://www.youtube.com/watch?v=_6Lgnb_0sps&list=PLToEf4XAd7Su1bWbUqqxjmTMKlv3fL63w&index=13

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

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A) Course Code : **2413405(T2413405/P2413405/S2413405)**

B) Course Title : Advance Refractory Technology

C) Pre- requisite Course(s) : Basic Refractory Technology

D) Rationale :

Advanced Refractory Technology aims to offer a complete understanding and practical knowledge of the sophisticated materials utilized in refractory applications. Refractories are of central importance in various industries such as metallurgy, cement, glass, petrochemicals, and others, as they exhibit exceptional resistance to elevated temperatures and hostile operating conditions. The Furnace operation cannot be carried out without having Refractory lining inside the Furnace. It encounters various hazards such as abrasion, thermal shock, slag attack, turbulence etc. This course imparts knowledge of oxide refractory, manufacturing process, properties, and application, testing of refractory products and provides diploma engineers with the necessary knowledge and skills to proficiently choose, design, implement, and sustain refractory materials in industrial environments.

E) Course Outcomes (COs): After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

After completion of the course, the students will be able to-

- **CO-1** Analyze the challenges faced during refractory production and application and propose potential solutions.
- **CO-2** Evaluate the quality and performance of refractory using various testing techniques.
- **CO-3** Evaluate the advantages and limitations of using different types of refractories in various high-temperature applications.
- **CO-4** Utilize phase diagrams to troubleshoot issues related to the performance of refractories in real-world applications.
- **CO-5** Select appropriate refractory materials based on the temperature, chemical environment, and mechanical stresses of a given application.

F) Suggested Course Articulation Matrix (CAM):

Course Outcomes (COs)	**Programme Outcomes (POs)**							**Programme Specific Outcomes* (PSOs)**	
	PO-1 Basic and Discipline Specific Knowledge	**PO-2** Problem Analysis	**PO-3** Design/ Development Solutions	**PO-4** Engineering Tools	**PO-5** Engineering Practices for Society, Sustainability and Environment	**PO-6** Project Management	**PO-7** Lifelong Learning	**PSO-1**	**PSO-2**
CO-1	3	-	-	-	-	-	1		
CO-2	3	2	2	2	1	-	1		
CO-3	3	2	2	2	2	-	2		
CO-4	3	2	1	2	2	-	1		
CO-5	3	2	3	2	2	2	2		

Legend: High (3), Medium (2), Low (1) and No mapping (-)

* PSOs will be developed by respective programme coordinator at institute level. As per latest NBA guidelines, formulating PSOs is optional.

G) Teaching & Learning Scheme:

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+ SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		L	T				
2413405	Advance Refractory Technology	03	-	04	02	09	06

Legend:

CI: Classroom Instruction (Includes different instructional/implementation strategies i.e. Lecture (L), Tutorial (T), Case method, Demonstrations, Video demonstration, Problem based learning etc. to deliver theoretical concepts)

LI: Laboratory Instruction (Includes experiments/practical performances /problem-based experiences in laboratory, workshop, field or other locations using different instructional/Implementation strategies)

Notional Hours: Hours of engagement by learners, other than the contact hours for ensuring learning.

TW: Term Work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

C: Credits = (1 x CI hours) + (0.5 x LI hours) + (0.5 x Notional hours)

Note: TW and SL have to be planned by the teacher and performed by the learner under the continuous guidance and feedback of teacher to ensure outcome of learning.

H) Assessment Scheme:

Course Code	Course Title	Assessment Scheme (Marks)						Total Marks (TA+TWA+LA)
		Theory Assessment (TA)		Term Work & Self-Learning Assessment (TWA)		Lab Assessment (LA)		
		Progressive Theory Assessment (PTA)	End Theory Assessment (ETA)	Internal	External	Progressive Lab Assessment (PLA)	End Laboratory Assessment (ELA)	
2413405	Advance Refractory Technology	30	70	20	30	20	30	200

Legend:

PTA: Progressive Theory Assessment in classroom (includes class test, mid-term test and quiz using online/offline modes)

PLA: Progressive Laboratory Assessment (includes process and product assessment using rating Scales and rubrics)

TWA: Term work & Self Learning Assessment (Includes assessment related to student performance in assignments, seminars, micro projects, industrial visits, self-learning, any other student activities etc.

Note:

- ETA & ELA are to be carried out at the end of the term/ semester.
- Term Work is to be done by the students under the guidance of internal faculty but its assessment will be done **internally (40%)** as well as **externally (60%)**. Assessment related to planning and execution of Term Work activities like assignment, micro project, seminar, and self-learning is to be done by internal faculty (Internal Assessment) whereas assessment of output/product/ presentation related to these activities will be carried out by external faculty/expert (External Assessment). However, criteria of internal as well as external assessment may vary as per the requirement of respective course. For valid and reliable assessment, the internal faculty should prepare checklist & rubrics for these activities.

I) Course Curriculum Detailing: This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) Theory Session Outcomes (TSOs) and Units: T2413405

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 1a. Explain requirement of refractory in various plant. *TSO 1b.* Differentiate between ancient refractory application practice and modern refractory application practice. *TSO 1c.* Use appropriate materials for refractory making. *TSO 1d.* Explain the significance of R&D in advancing refractory technology and enhancing its performance.	**Unit-1.0 Introduction** 1.1 Scenario of Refractory Production and demand 1.2 Ancient and Modern refractory practices 1.3 Refractory design parameters 1.4 Challenges in production and application 1.5 Role of research and development (R&D) in Refractory industry.	**CO1**
TSO 2a. Classify refractories properties on given criteria. *TSO 2b.* Explain various properties of refractory. *TSO 2c.* Explain various methods for refractory testing. *TSO 2d.* Apply testing data in application of Refractory *TSO 2e.* Apply standard testing methods such as ASTM or ISO to determine the properties of refractory materials	**Unit-2.0 Properties and Testing of Refractory** 2.1 Physical Properties: Apparent Porosity, Total Porosity, Bulk Density, Specific Gravity, Firing Shrinkage 2.2 Mechanical Properties: CCS, CMOR 2.3 Thermal Properties: Thermal Expansion, Thermal Conductivity 2.4 Thermal Properties: HMOR, Creep 2.5 Thermo-mechanical Properties 2.6 Abrasion Properties 2.7 Corrosion Properties: Carbon Monoxide Disintegration, Slag or Glass Corrosion 2.8 Refractory Specific Properties: PCE, RUL, Thermal Shock Resistance, PLCR	**CO2**
TSO 3a. Describe the equipment's required for Manufacturing of Various refractory. *TSO 3b.* Explain properties of given refractory. *TSO 3c.* Explain critical areas of furnace of refractory lining with examples. *TSO 3d.* Differentiate between shaped and unshaped refractories. *TSO 3e.* Explain the applications of Muffles, Saggers, Crucibles.	**Unit-3.0 Manufacturing, Properties and Uses of Refractory** 3.1 Silica Refractory: Raw Materials and Sources, Manufacture method, Mineralizer, effect of impurities, uses, residual quartz. 3.2 Alumina Refractory: Raw material and sources, manufacturing method, effect of impurities, uses. 3.3 Fireclay Refractory: Raw Materials and Sources, grog, manufacturing method, classification, uses. 3.4 Magnesia Refractory: Raw Materials and Sources, Manufacture method, effect of impurities, uses. 3.5 Dolomite Refractory: Raw Materials and Sources, Manufacture method, effect of impurities, uses. 3.6 Chromite Refractory: Raw Materials and Sources, Manufacture method, Classification, effect of impurities, uses. 3.7 Magnesia Carbon Refractory: Raw materials, binders, additives, Manufacture method, role of carbon, uses. 3.8 Special Refractories: Fused cast refractory, Fused cast alumna, AZS, fused cast zirconia, fused cast alumina- zirconia, fused cast alumina silica, insulating refractory, ceramic fibers, Silicon carbide 3.9 Unshaped Refractories: introduction, Classification, raw materials, and additives, uses, 3.10 Refractory Products: Muffles, Saggers, Crucibles	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO 4a. Explain various phase diagrams used for refractory manufacturing. *TSO 4b.* Use the concept of phase diagram in refractory applications. *TSO 4c.* Explain various invariant points in phase diagram.	**Unit-4.0 Application of Phase Diagram in Refractory** 4.1 Silica-Alumina Phase diagram 4.2 Magnesia- Alumina Phase Diagram 4.3 Lime- Alumina Phase Diagram 4.4 Lime- Silica Phase Diagram 4.5 Lime- Magnesia Phase Diagram 4.6 Iron- Carbon Phase Diagram	**CO4**
TSO 5a. Choose suitable refractory for various furnaces in iron and steel plant. *TSO 5b.* Explain lining of cement rotary kiln of different zones. *TSO 5c.* Analyze atmosphere, application temperature and other criteria of furnace in various industries.	**Unit-5.0 Application of Refractory** 5.1 Iron and Steel Industries 5.2 Non-Ferrous Industries 5.3 Glass Industries 5.4 Cement Industries 5.5 Lime Industries 5.6 Power Plant 5.7 Petro-chemical Industries	**CO5**

Note: One major TSO may require more than one Theory session/Period.

K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2413405

Practical/Lab Session Outcomes (LSOs)	S.No.	LaboratoryExperiment /Practical Titles	Relevant COs Number(s)
LSO 1.1. Prepare sample for bulk density measurement. *LSO 1.2.* Apply formula for calculation of bulk density. *LSO 1.3.* Interpretate result with standard data.	1.	Determination bulk density of a given sample of refractory.	CO2
LSO 2.1. Prepare sample for apparent porosity measurement. *LSO 2.2.* Use instruments like weighing machine, flask, vacuum machine, boiling machine. *LSO 2.3.* Apply formula for calculation of apparent porosity.	2.	Determination of Apparent porosity of a given sample of refractory.	CO2
LSO 3.1. Prepare sample for water absorption measurement. *LSO 3.2.* Use various tools weighing machine, flask, vacuum machine, boiling machine. *LSO 3.3.* Apply formula for calculation of water absorption.	3.	Determination of water absorption of a given sample of refractory.	CO2
LSO 4.1. Prepare sample for cold crushing strength measurement. *LSO 4.2.* Use pressing machine.	4.	Determination of cold crushing strength of a given sample of refractory.	CO2
LSO 5.1. Prepare sample for refractoriness measurement. *LSO 5.2.* Use furnace for heating sample and reference sample	5.	Determination refractoriness of a given sample of refractory.	CO3, CO4
LSO 6.1. Prepare batch of fire clay for making refractory brick. *LSO 6.2.* Use mould for shaping.	6.	Making a fire clay-based bricks using hand moulding.	CO2, CO3, CO4
LSO 7.1. Select an appropriate kiln for drying and firing of refractory. *LSO 7.2.* Operate kiln for drying and firing. *LSO 7.3.* Select apparatus for measurement of Dimension.	7.	Determination of drying and firing shrinkage of fire clay refractory.	CO3, CO4

L) Suggested Term Work and Self Learning: S2413405 Some sample suggested assignments, micro project and other activities are mentioned here for reference.

a. Assignments: Questions/Problems/Numerical/Exercises to be provided by the course teacher in line with the targeted COs.

1. Study a refractory material's qualities, manufacture, and uses. Present your findings in a report or presentation.
2. Study real-world industrial refractory applications to understand the difficulties, materials, and solutions.
3. Choose a refractory material for an industrial application and justify it based on qualities and conditions and present the findings in the class.
4. Ask the students to read phase diagrams of refractory systems to forecast their high-temperature behavior.

b. Micro Projects:

1. Test samples of industrial refractory materials for bulk density, thermal conductivity, and compressive strength and write a report.
2. Build a miniature industrial furnace or kiln model and show refractory liner installation.
3. Simulate a real-world industrial furnace application by selecting refractory materials. Consider temperature ranges, chemical exposure, mechanical stress, and prepare a report on the same.
4. Create and test an insulating refractory material to prevent heat loss in industrial furnaces and ovens to **save energy.**
5. Prepare a report exploring the recycling possibilities of discarded refractory materials and proposing new uses.

c. Other Activities:

1. Seminar Topics:
   - Recent Advances in Refractory Materials
   - Role of Refractories in Sustainable Manufacturing
   - Refractory Failure Analysis and Prevention
   - Insulating Refractories for **Energy Conservation**
   - Refractories for Space Exploration
   - Environmental Impact of Refractory Materials
2. Visits: Visit nearby industry of bricks manufacturing. Prepare report of visit with special comments of material used for bricks manufacturing, process applied, major application area, major consumer, costing.
3. Self-Learning Topics:
   - Advance manufacturing techniques.
   - Refractory material selection
   - Failure analysis
   - Alternative and sustainable refractories

M) Suggested Course Evaluation Matrix: The course teacher has to decide and use appropriate assessment strategy and its weightage in theory, laboratory and Term Work for ensuring CO attainment. The response/performance of each student in each of these designed activities is to be used to calculate **CO attainment**.

COs	Course Evaluation Matrix						
	Theory Assessment (TA)**		**Term Work Assessment (TWA)**			**Lab Assessment (LA)#**	
	Progressive Theory Assessment (PTA) Class/Mid Sem Test	**End Theory Assessment (ETA)**	**Term Work & Self Learning Assessment**			**Progressive Lab Assessment (PLA)**	**End Laboratory Assessment (ELA)**
			Assignments	**Micro Projects**	**Other Activities***		
CO-1	15%	10%	15%	-	-	20%	20%
CO-2	10%	15%	10%	25%	-	10%	20%
CO-3	15%	20%	15%	25%	33%	15%	20%
CO-4	30%	15%	30%	25%	33%	15%	20%
CO-5	30%	30%	30%	25%	34%	40%	20%
Total Marks	**30**	**70**	**20**	**20**	**10**	**20**	**30**
			50				

Legend:

*: Other Activities include self- learning, seminar, visits, surveys, product development, software development etc.

**: Mentioned under point- (N)

#: Mentioned under point-(O)

Note:

- The percentage given are approximate
- In case of Micro Projects and End Laboratory Assessment (ELA), the achieved marks will be equally divided in all those COs mapped with total experiments.
- For CO attainment calculation indirect assessment tools like course exit survey need to be used which comprises of questions related to achievement of each COs.

N) Suggested Specification Table for End Semester Theory Assessment: Specification table represents the reflection of sample representation of assessment of cognitive domain of full course.

Unit Title and Number	Total Classroom Instruction (CI) Hours	Relevant COs Number(s)	Total Marks	ETA (Marks)		
				Remember (R)	Understanding (U)	Application & above (A)
Unit-1.0 Introduction	6	CO1	10	4	4	2
Unit-2.0 Properties and Testing of Refractory	8	CO2	12	3	4	5
Unit-3.0 Manufacturing, Properties and uses of Refractory	11	CO3	16	4	5	7
Unit-4.0 Application of Phase Diagram in Refractory	10	CO4	12	4	4	4
Unit-5.0 Application of Refractory	13	CO5	20	5	7	8
Total	**48**	**-**	**70**	**20**	**24**	**26**

Note: Similar table can also be used to design class/mid-term/ internal question paper for progressive assessment.

O) Suggested Assessment Table for Laboratory (Practical):

S. No.	Laboratory Practical Titles	Relevant COs Number (s)	PLA/ELA		
			Performance		Viva-Voce (%)
			PRA* (%)	PDA** (%)	
1.	Determine the bulk density of a given sample of refractory.	CO2	30	60	10
2.	Determine the Apparent porosity of a given sample of refractory.	CO2	40	50	10
3.	Determine water absorption of a given sample of refractory.	CO2	30	60	10
4.	Determine cold crushing strength of a given sample of refractory.	CO2	30	60	10
5.	Determine refractoriness of a given sample of refractory.	CO3, CO4	30	60	10
6.	Make a fire clay-based bricks using hand moulding.	CO2, CO3, CO4	30	60	10
7.	Determine drying and firing shrinkage of fire clay refractory.	CO2, CO3, CO4	30	60	10

Legend:

PRA*: Process Assessment
PDA**: Product Assessment

Note: This table can be used for both end semester as well as progressive assessment of practical. Rubrics need to be prepared by the course teacher for each experiment/practical to assess the student performance.

P) Suggested Instructional/Implementation Strategies:

Suggested Instructional/Implementation Strategies: Different Instructional/ Implementation Strategies may be appropriately selected, as per the requirement of the content/outcome. Some of them are Improved Lecture, Tutorial, Case Method, Group Discussion, Industrial visits, Industrial Training, Field Trips, Portfolio Based, Learning, Role Play, Live Demonstrations in Classrooms, Lab, Field Information and Communications Technology (ICT)Based Teaching Learning, Blended or flipped mode, Brainstorming, Expert Session, Video Clippings, Use of Open Educational Resources (OER), MOOCs etc.

Q) List of Major Laboratory Equipment, Tools and Software:

S. No.	Name of Equipment, Tools and Software	Broad Specifications	Relevant Experiment/PracticalNumber
1.	Electronic balance	Balance Type- Digital, Range- 0.1-1000 gm,	1,2,3
2.	Hot Plate	Material- Stainless steel, Capacity- 1000 watt or more, Max Temp. - 350 Degree, Power supply- 230 volt	1,2,3
3.	Vacuum chamber	Laboratory type	1,2,3
4.	CCS testing machine	Laboratory type	4
5.	Electric Dryer	Temperature Range- 50-200^{o} C, Size-18’’*18’’*18’’	5,6,7
6.	Electric Furnace	Temperature Range- 1600^{o}C-2000^{o}C, Size of chamber – 18’’*18’’*18’’	5, 6,7
7.	Refractory Brick Mould Die	Made of steel, Size- 230*115*75 mm, 125*50*50 mm	6

R) Suggested Learning Resources:

(a) Books:

S. No.	Titles	Author(s)	Publisher and Edition with ISBN
1.	Ceramic Materials Formation	R. P. Sinha	Novelty; 2nd Edition, ASIN: B083W91KDL
2.	Refractory Technology Fundamentals and Applications	Ritwik Sarkar	Publisher: 1s CRC Press; st edition ISBN-10: 0367574292
3.	Industrial Ceramics	F. Singer and S.S. Singer	Publisher: Springer ISBN- 10: 9401752591
4.	Handbook of glass technology	Dr. R. Chavan	Publisher: WileyAmerican Ceramic - Societ ISBN-10: 1119219868
5.	Refractories	F. H. Norton	Publisher : McGraw-Hill ISBN-10 : 0070475385
6.	Refractories Production and Properties	J. H. Chesters	Publisher: W.P. : ISBN- 10:1845691202

(b) Online Educational Resources:

1. https://en.wikipedia.org/wiki/Ceramic
2. https://en.wikipedia.org/wiki/Ceramic_engineering
3. https://www.youtube.com/watch?v=7Be7hGvqoAg
4. https://archive.org/details/dli.ernet.239153

Note: Teachers are requested to check the creative commons license status/ financial implications of the suggested, online educational recourses before use by the students.

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