Gyanmanjari Innovative University

Syllabus
Gyanmanjari Institute of Technology
Semester-3 (B. Tech)

Subject: Industrial Mechanical Operations-BET2CH13303

Type of course: Professional Core

Prerequisite: Basic knowledge related to properties of solid and solid-fluid interaction

Rationale: Studying the fundamental mechanical processes (size reduction, mixing, solid-solid and solid-fluid separation, etc.) occurring in the process industry is the primary goal of this course. Additionally, it offers a platform for researching and analyzing different features related to when the solid is in a state of flow. This course covers the basic principles of particle size reduction and expansion using a variety of techniques, as well as the intricate design and operation of mechanical equipment.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks		Total Marks
CI	T	P	C	SEE	CCE	
2	0	4	4	100	50	150

Legends: CI-Classroom Instructions; T-Tutorial; P -Practical; C –Credit; SEE - Semester End Evaluation; CCE-Continuous Class Evaluation.

GYANMANJARI INNOVATIVE UNIVERSITY BHAVNAGAR

Course Content:

<table>
<tr><th>Sr. No.</th><th>Course Content</th><th>Hrs.</th><th>% Weightage</th></tr>
<tr><td>1</td><td>
Solids and Its Flow Properties:

Theory Topics:
Introduction to Solids and their importance in Chemical and Mechanical Engineering industries. Characteristics of solid particles such as size, shape, density, porosity, and surface properties. Properties of particulate masses including bulk density, voidage, angle of repose, flowability, and compressibility. Study of particle size and methods of particle size analysis. Mixed particle size analysis and determination of average particle size. Specific surface area of mixtures and calculation of the number of particles in a mixture. Introduction to screen analysis and standard screens used in industries. Capacity and effectiveness of screens. Comparison between ideal and actual screens. Study of screening equipment such as Grizzly Screens, Gyrating Screens, Trommels, Vibrating Screens, and Oscillating Screens along with their construction, working principles, advantages, and industrial applications.

Practical:
1. Determine bulk density and angle of repose of a particulate material.
2. Perform sieve analysis for a given solid mixture and determine particle size distribution.
3. Calculate average particle size and specific surface area from sieve analysis data.
4. Determine the capacity and effectiveness of a screen using standard screens.
5. Study and compare ideal and actual screening operations.
6. Determine the voidage (porosity) of a packed bed of solid particles.
7. Solve numerical problems related to particle size analysis, screen effectiveness, and particulate properties.
8. Determine the flowability index of a particulate material using Carr's Index and Hausner Ratio.
9. Demonstrate and compare the working of Grizzly Screens, Gyrating Screens, Trommels, Vibrating Screens, and Oscillating Screens.

Evaluation Method:
<table>
<tr><th>Sr. No.</th><th>Evaluation Methods</th><th>SEE</th><th>CCE</th></tr>
<tr><td>1</td><td>Particle Size Analysis and Screening Experiment: Students will perform sieve analysis, determine average particle size, and calculate screen effectiveness using standard procedures.</td><td>20</td><td></td></tr>
<tr><td>2</td><td>Active Learning Assignment: Industrial</td><td></td><td>10</td></tr>
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</td><td>18</td><td>20 %</td></tr>
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			Screening Equipment Study: Students will prepare a comprehensive report and deliver a presentation using Canva on various industrial screening equipment, including Vibrating Screens, Trommels, and Gyrating Screens. The study should cover the construction, working principles, performance characteristics, advantages, limitations, and industrial applications of each screening device.			
			Total	**20**	**10**	

Examination Style:

Particle Size Analysis and Screening Experiment (20 Marks)
Students will conduct sieve analysis on a given particulate sample to determine particle size distribution, average particle size, and screen effectiveness. Students will also perform calculations related to specific surface area, bulk density, and number of particles in the mixture. Viva questions related to screening equipment and solid flow properties will also be included.

Industrial Screening Equipment Study (10 Marks)
Students shall prepare a short technical report and presentation on industrial screening equipment including Grizzly Screens, Vibrating Screens, Trommels, Gyrating Screens, and Oscillating Screens. The report should include construction, working principle, industrial applications, advantages, limitations, and labeled diagrams wherever necessary.

2	**Size Reduction** **Theory Topics:** Introduction to size reduction and its importance in Chemical, Pharmaceutical, Food, Cement, and Mineral processing industries. Principles of comminution and mechanisms of size reduction such as compression, impact, attrition, and cutting. Study of Rittinger's Law, Kick's Law, and Bond's Crushing Law with industrial applications and limitations. Introduction to Bond Work Index and energy requirements for crushing and grinding operations. Classification and working principles of size reduction equipment such as crushers, grinders, and ultra-fine grinders. Study of primary and secondary crushers including Jaw Crushers, Gyratory Crushers, Roll Crushers, and Hammer Mills. Study of grinding equipment such as Ball Mills, Rod Mills, Attrition Mills, and Fluid Energy Mills. Ultra-fine grinding operations and their applications in industries. Comparison between dry grinding and wet grinding processes with advantages and limitations. Study of cutting machines used for fibrous and soft materials. Open circuit and closed-circuit size reduction operations along with industrial applications, advantages, and process flow diagrams. **Practical:** 10. Study the construction and working of Jaw Crusher, Roll Crusher, and Hammer Mill.	18	20 %

11. Determine crushing efficiency and reduction ratio of a crusher.
12. Perform grinding operation using Ball Mill and calculate critical speed.
13. Compare dry grinding and wet grinding operations for a given material.
14. Demonstrate the working of ultra-fine grinders and cutting machines.
15. Study open circuit and closed-circuit grinding operations using process flow diagrams.
16. Solve numerical problems based on Rittinger's Law, Kick's Law, Bond's Crushing Law, work index, and energy calculations.
17. Determine Bond Work Index and estimate the energy requirement for a grinding operation.
18. Analyze particle size distribution before and after crushing/grinding using sieve analysis.

Evaluation Method:

Sr. No.	Evaluation Methods	SEE	CCE
1	**Size Reduction Experiment:** Students will perform crushing and grinding operations, determine reduction ratio, crushing efficiency, and calculate energy requirements using standard laws of Crushing	20	
2	**Active Learning Assignment: Industrial Size Reduction Equipment Study:** Students will design and develop 3D models of various size reduction equipment, such as Jaw Crushers, Roll Crushers, Hammer Mills, Ball Mills, and Fluid Energy Mills, using CAD software such as SolidWorks, ANSYS, or equivalent tools. They will prepare a technical report and deliver a presentation covering the construction, working principles, operating parameters, performance characteristics, and industrial applications of the selected equipment.		10
	Total	**20**	**10**

Examination Style:

Size Reduction Experiment (20 Marks)

Students will conduct crushing and grinding operations on a given material to determine reduction ratio, crushing efficiency, and energy requirements. Students will also perform calculations related to Rittinger's Law, Kick's Law, Bond's Crushing Law, Bond Work Index, and critical speed of ball mill. Viva questions related to comminution principles,

	grinding equipment, dry and wet grinding, and industrial applications will also be included. **Industrial Size Reduction Equipment Study (10 Marks)** Students shall prepare a design and presentation on industrial size reduction equipment including Jaw Crushers, Roll Crushers, Hammer Mills, Ball Mills, Rod Mills, and Fluid Energy Mills. The report should include construction, working principle, industrial applications, advantages, limitations, and labeled diagrams wherever necessary.		
3	**Filtration and Sedimentation:** **Theory Topics:** Introduction to filtration and sedimentation processes and their importance in chemical, pharmaceutical, food, water treatment, and mineral processing industries. Principles of cake filtration and factors affecting filtration rate. Study of filter media and filter aids used in industrial filtration processes. Construction, working principles, advantages, limitations, and industrial applications of filtration equipment such as Filter Press, Shell and Leaf Filters, Rotary Vacuum Drum Filters, and Clarifying Filters. Introduction to centrifugation and classification of centrifuges with industrial applications. Principles and applications of gravity classifiers, clarifiers, and thickeners. Study of sink and float separation methods. Batch sedimentation and rate of sedimentation. Differential settling methods and sedimentation zones in continuous thickeners. Study of cyclone separators and hydrocyclones for particle separation. Introduction to air pollution control and dust collection equipment such as Bag Filters, Wet Scrubbers, and Electrostatic Precipitators along with construction, working principles, advantages, and industrial applications. **Practical:** 19. Study the construction, working principle, and industrial application of Filter Press. 20. Study the operation and filtration mechanism of Shell and Leaf Filter. 21. Demonstrate the working and performance characteristics of Rotary Vacuum Drum Filter. 22. Perform settling analysis using a Batch Sedimentation Tank and determine settling velocity of particles. 23. Study sedimentation zones and sludge thickening using a Continuous Thickener. 24. Demonstrate particle separation using a Cyclone Separator and determine separation efficiency. 25. Study the construction and working of a Hydrocyclone for liquid-solid separation. 26. Demonstrate centrifugal separation using a Centrifuge and study its industrial applications. 27. Study the dust collection mechanism and performance of a Bag Filter.	18	20%

28. Demonstrate the operation and pollution control efficiency of a Wet Scrubber.
29. Study the construction, working principle, and applications of an Electrostatic Precipitator (ESP).

Evaluation Method:

Sr. No.	Evaluation Methods	SEE	CCE
1	**Filtration and Sedimentation Experiment:** Students will perform experiments on filtration, sedimentation, cyclone separation, and centrifugal separation equipment to determine filtration rate, settling velocity, and separation efficiency using standard procedures.	20	
2	**Active Learning Assignment:** *Industrial Separation Equipment Study:* Students will prepare a technical design and presentation on industrial separation equipment such as Filter Press, Rotary Vacuum Drum Filter, Hydrocyclone, Centrifuge, Wet Scrubber, and Electrostatic Precipitator including construction, working principles, and industrial applications.		10
	Total	**20**	**10**

Examination Style:

Filtration and Sedimentation Experiment (20 Marks)
Students will conduct practical experiments on industrial filtration and sedimentation equipment such as Filter Press, Rotary Vacuum Drum Filter, Cyclone Separator, Hydrocyclone, and Centrifuge. Students will determine filtration rate, settling velocity, and separation efficiency using standard procedures. Numerical calculations related to cake filtration, sedimentation rate, cyclone efficiency, and centrifugal separation will also be performed. Viva questions related to filtration principles, sedimentation zones, dust collection equipment, and industrial applications will also be included.

Industrial Separation Equipment Study (10 Marks)
Students shall prepare a design and presentation on industrial separation and pollution control equipment including Filter Press, Shell and Leaf Filter, Rotary Vacuum Drum Filter, Cyclone Separator, Hydrocyclone, Centrifuge, Bag Filter, Wet Scrubber, and Electrostatic Precipitator. The report should include construction, working principle, industrial applications, advantages, limitations, and labeled diagrams wherever necessary.

4	**Fluidization and Conveying:** **Theory Topics:** Introduction to fluidization and conveying operations and their importance in chemical, pharmaceutical, fertilizer, cement, food, and mineral processing industries. Conditions required for fluidization and classification of fluidized beds. Types of fluidizations such as particulate fluidization and aggregative fluidization. Minimum fluidization velocity and pressure drop in fluidized beds. Study of Kozeny–Carman Equation, Burke–Plummer Equation, and Ergun Equation with industrial applications. Liquid-solid and gas-solid fluidized systems and their characteristics. Applications of batch and continuous fluidization systems in industries. Introduction to slurry transport and pneumatic transport systems. Principles, construction, working, advantages, limitations, and industrial applications of mechanical and pneumatic conveying systems. Study of conveying equipment such as belt conveyors, screw conveyors, bucket elevators, chain conveyors, and pneumatic conveyors. Study of elevators, storage bins, hoppers, and silos for handling solids, liquids, and gases along with safety considerations and industrial applications. **Practical:** 30. Study the construction and working of a Fluidized Bed Apparatus and determine minimum fluidization velocity. 31. Determine pressure drop across a Fluidized Bed Column at different flow rates. 32. Verify fluidization behavior using the Ergun Equation and compare theoretical and experimental values. 33. Study the working and conveying characteristics of a Belt Conveyor. 34. Demonstrate the operation and material handling mechanism of a Screw Conveyor. 35. Study the construction and working principle of a Bucket Elevator used in industries. 36. Demonstrate solid transport using a Pneumatic Conveying System. 37. Study slurry transport and flow characteristics using a Slurry Transport Setup. 38. Study the construction and discharge characteristics of Storage Bins and Silos. **Evaluation Method:**	18	20%

Sr. No.	Evaluation Methods	SEE	CCE
1	**Fluidization and Conveying Experiment:** Students will perform experiments on fluidized bed systems, pneumatic conveying systems, and mechanical conveying equipment to determine minimum fluidization velocity, pressure drop, and conveying efficiency	20	

	using standard procedures.		
2	***Problem-based Learning Activity:*** *Industrial Fluidization and Conveying Equipment Study:* Students will undertake a problem-based learning (PBL) activity involving the analysis and design of industrial fluidization and conveying systems. They will prepare a technical case study, CAD-based model, and presentation on equipment such as Fluidized Beds, Belt Conveyors, Screw Conveyors, Bucket Elevators, Pneumatic Conveyors, Storage Bins, and Silos. The study will include the constructional features, operating principles, design considerations, performance characteristics, and industrial applications of the selected equipment. Students will utilize CAD software (SolidWorks, AutoCAD, ANSYS, etc.) to develop 3D models and demonstrate the functionality of the equipment while proposing solutions to real industrial material handling and fluidization challenges.		10
	Total	**20**	**10**

Examination Style:

Fluidization and Conveying Experiment (20 Marks)
Students will conduct practical experiments on Fluidized Bed Apparatus, Belt Conveyors, Screw Conveyors, Bucket Elevators, Pneumatic Conveying Systems, and Slurry Transport Systems. Students will determine minimum fluidization velocity, pressure drop, and conveying characteristics using standard procedures. Numerical calculations related to Ergun Equation, Kozeny–Carman Equation, conveying efficiency, slurry transport, and pneumatic transport will also be performed. Viva questions related to fluidization principles, conveying systems, storage bins, silos, and industrial applications will also be included.

Industrial Fluidization and Conveying Equipment Study (10 Marks)
Students shall prepare a design of industrial fluidization and conveying systems. They will prepare a technical case study, CAD-based model, and presentation on equipment such as Fluidized Beds, Belt Conveyors, Screw Conveyors, Bucket Elevators, Pneumatic Conveyors, Storage Bins, and Silos. The report should include constructional features, operating principles, design considerations, performance characteristics, and industrial applications of the selected equipment. Students will utilize CAD software (SolidWorks, AutoCAD, ANSYS, etc.) to develop 3D models and demonstrate the functionality of the equipment while proposing solutions to real industrial material handling and fluidization

	challenges.		
5	**Mixing and Agitation:** **Theory Topics:** Introduction to mixing and agitation operations and their importance in chemical, pharmaceutical, food, cosmetic, and polymer industries. Objectives of mixing and factors affecting mixing efficiency. Different types of agitators and their selection criteria based on fluid properties and process requirements. Study of various types of impellers such as propellers, turbines, paddles, and anchors. Flow patterns in un-baffled and baffled tanks and their effects on mixing efficiency. Calculation of power required for agitation and factors affecting power consumption. Scale-up of agitated vessels and industrial considerations in scale-up operations. Mixing of liquids, pastes, slurries, and dry powders. Construction, working principles, advantages, limitations, and industrial applications of mixing equipment such as Pony Mixer, Ribbon Blender, Tumbler Mixer, Static Mixer, and Gas Induction Type Agitator. Introduction to gas-liquid mixing systems and applications in industries. **Practical:** 39. Study the construction and working of a Propeller Agitator used for liquid mixing. 40. Demonstrate mixing characteristics and flow patterns using a Turbine Agitator in baffled and un-baffled tanks. 41. Determine power consumption and mixing efficiency of a Paddle Agitator. 42. Study the operation and industrial applications of an Anchor Agitator for viscous fluids. 43. Demonstrate dry powder mixing using a Ribbon Blender. 44. Study the construction and mixing mechanism of a Tumbler Mixer. 45. Demonstrate continuous mixing operation using a Static Mixer. 46. Study gas-liquid mixing and aeration using a Gas Induction Type Agitator. 47. Study pastes mixing characteristics using a Pony Mixer. 48. Solve numerical problems related to power requirement, agitator design, scale-up of agitated vessels, and mixing efficiency. **Evaluation Method:** <table><tr><th>Sr. No.</th><th>Evaluation Methods</th><th>SEE</th><th>CCE</th></tr><tr><td>1</td><td>**Mixing and Agitation Experiment:** Students will perform experiments on agitators and industrial mixing equipment to determine mixing efficiency, flow patterns, power consumption, and operational characteristics using standard procedures.</td><td>20</td><td></td></tr><tr><td>2</td><td>**Problem-based Learning Assignment:** ***Industrial Mixing Equipment Study:***</td><td></td><td>10</td></tr></table>	18	20 %

		Students will prepare a technical assignment and presentation on industrial mixing and agitation equipment such as Propeller Agitators, Turbine Agitators, Ribbon Blenders, Tumbler Mixers, Static Mixers, and Gas Induction Type Agitators including construction, working principles, and industrial applications.			
		Total	**20**	**10**	

Examination Style:

Mixing and Agitation Experiment (20 Marks)
Students will conduct practical experiments on Propeller Agitators, Turbine Agitators, Paddle Agitators, Ribbon Blenders, Tumbler Mixers, Static Mixers, and Gas Induction Type Agitators to study mixing efficiency, flow patterns, and power consumption. Students will also perform calculations related to agitator power requirement, mixing characteristics, scale-up of agitated vessels, and mixing efficiency. Viva questions related to baffled and un-baffled tanks, impeller selection, industrial mixing equipment, and industrial applications will also be included.

Industrial Mixing Equipment Study (10 Marks)
Students shall prepare a short technical assignment and presentation on industrial mixing and agitation equipment including Propeller Agitators, Turbine Agitators, Paddle Agitators, Anchor Agitators, Ribbon Blenders, Tumbler Mixers, Pony Mixers, Static Mixers, and Gas Induction Type Agitators. The report should include construction, working principle, industrial applications, advantages, limitations, safety considerations, and labeled diagrams wherever necessary.

Suggested Specification table with Marks (Theory): 100

Distribution of Theory Marks (Revised Bloom's Taxonomy)						
Level	Remembrance (R)	Understanding (U)	Application (A)	Analyze (N)	Evaluate (E)	Create (C)
Weightage %	15%	15%	20%	15%	15%	20%

Course Outcome:

After learning the course, the students should be able to:	
CO1	Characterize particles and perform size reduction and size analysis of particles to meet the need of chemical industries.

CO2	Review the practical importance and relevance of unit operations used for size reduction and separation in the chemical industry.
CO3	Evaluate various operating parameters of filtration and sedimentation equipment
CO4	Understand fluid-solid behavior during fluidization and conveying.
CO5	Identify the different types of mixing and agitation and estimate the power requirement.

Instructional Method:

The course delivery method will depend upon the requirement of content and the needs of students. The teacher, in addition to conventional teaching methods by black board, may also use any tools such as demonstration, role play, Quiz, brainstorming, MOOCs etc.

The internal evaluation will be done on the basis of continuous evaluation of students in the laboratory and class-room.

Students will use supplementary resources such as online videos, NPTEL videos, e-courses, Virtual Laboratory

Reference Books:

[1] Foust A. S. & associates, "Principles of Unit Operations" John Wiley and Sons (1980).

[2] McCabe Smith, "Unit Operation in Chemical Engineering" 5th ed. McGraw Hill (1985).

[3] Perry R.H. & Chilton C.H., "Chemical Engineers Hand Book", 7th ed. McGraw hill.

[4] Badger and Bencharo, "Introduction to Chemical Engineering". Tata McGraw hill.

[5] Coulson and Richardson: Chemical Engineering, Vol. 2, Butterworth Heinemann Pub.

[6] Narayanan C.M.& Bhattacharya B.C. "Mechanical Operations for Chemical engineers", Khanna Publishers. 3rd Ed.1999.

Suggested Assessment Guidelines:

Module-1: Solids and Its Flow Properties

Particle Size Analysis and Screening Experiment: (20 Marks)		
Criteria	**Description**	**Marks**
Sample Preparation	Proper collection, weighing, and preparation of particulate sample before sieve analysis following standard laboratory procedures.	5
Sieve Analysis	Correct arrangement and operation of standard sieves to determine particle size distribution accurately.	5
Calculations	Accurate calculation of average particle size, percentage retained, percentage passing, and screen effectiveness using experimental data.	5

Observation & Viva	Proper recording of observations, result interpretation, and answering viva questions related to screening principles and equipment.	5
Total		20

Module-2: Size Reduction

Size Reduction Experiment: (20 Marks)		
Criteria	**Description**	**Marks**
Equipment Handling	Proper setup and operation of crushing and grinding equipment such as Jaw Crusher and Ball Mill following standard laboratory procedures.	5
Experiment Performance	Correct execution of crushing and grinding operations and determination of reduction ratio and crushing efficiency accurately.	5
Calculations	Accurate calculation of energy requirements using Rittinger's Law, Kick's Law, and Bond's Crushing Law based on experimental data.	5
Observation & Viva	Proper recording of observations, result interpretation, and answering viva questions related to comminution principles and size reduction equipment.	5
Total		20

Module-3: Filtration and Sedimentation

Filtration and Sedimentation Experiment:(20 Marks)		
Criteria	**Description**	**Marks**
Equipment Handling	Proper setup and operation of filtration and separation equipment such as Filter Press, Cyclone Separator, and Centrifuge following standard laboratory procedures.	5
Experiment Performance	Correct execution of filtration, sedimentation, cyclone separation, and centrifugal separation experiments to determine filtration rate and settling velocity accurately.	5
Calculations	Accurate calculation of filtration rate, settling velocity, cyclone efficiency, and separation efficiency using experimental observations and standard equations.	5
Observation & Viva	Proper recording of observations, interpretation of results, and answering viva questions related to filtration, sedimentation, and industrial separation equipment.	5
Total		20

Module-4: Fluidization and Conveying

Fluidization and Conveying Experiment: (20 Marks)		
Criteria	**Description**	**Marks**
Equipment Handling	Proper setup and operation of Fluidized Bed Apparatus, Pneumatic Conveying System, and mechanical conveying equipment following standard laboratory procedures.	5
Experiment Performance	Correct execution of fluidization and conveying experiments to determine minimum fluidization velocity, pressure drop, and conveying characteristics accurately.	5
Calculations	Accurate calculation of minimum fluidization velocity, pressure drop, conveying efficiency, and pneumatic transport parameters using experimental data and standard equations.	5
Observation & Viva	Proper recording of observations, interpretation of results, and answering viva questions related to fluidization principles, conveying systems, and industrial applications.	5
Total		20

Module-5: Mixing and Agitation

Mixing and Agitation Experiment:(20 Marks)		
Criteria	**Description**	**Marks**
Equipment Handling	Proper setup and operation of agitators and industrial mixing equipment such as Propeller Agitator, Turbine Agitator, and Ribbon Blender following standard laboratory procedures.	5
Experiment Performance	Correct execution of mixing and agitation experiments to determine mixing efficiency, flow patterns, and operational characteristics accurately.	5
Calculations	Accurate calculation of power consumption, mixing efficiency, and agitator performance parameters using experimental data and standard equations.	5
Observation & Viva	Proper recording of observations, interpretation of results, and answering viva questions related to mixing principles, agitator types, and industrial applications.	5
Total		20