Gyanmanjari Innovative University

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

Subject: Chemical Process Calculations-BET2CH13304

Type of course: Professional Core

Prerequisite: Basics of Mathematics and Chemistry

Rationale:

The main objective of this subject is to develop an understanding of the basic calculations used in chemical processes carried out in fertilizer, dye, petrochemical, and specialty chemical industries. The subject also provides fundamental knowledge required for the preparation and interpretation of chemical process flow sheets.

Teaching and Examination Scheme:

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

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

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>
Units, Dimensions and Basic Chemical Calculations
Theory Topics:
Dimensions and system of units, fundamental and derived units, unit conversion and its significance, dimensional consistency, dimensional equations. Concepts of atomic weight, equivalent weight and mole. Composition of solids, liquids and solutions (weight percent, mole percent, molarity, normality etc.), concentration expressions, average molecular weight and density. Gaseous mixtures, Ideal Gas Laws and applications, Raoult's Law, Henry's Law, Amagat's Law & Dalton's Law, humidity and saturation.
Practical:
1. Perform unit conversions between different systems of units (SI, CGS, FPS) and verify the dimensional consistency of engineering equations.
2. Measure the density and specific gravity of different liquids using a pycnometer or hydrometer.
3. Prepare standard solutions of known molarity and normality and standardize them using titration techniques.
4. Calculate weight percent, mole percent, mole fraction, average molecular weight, and density of binary liquid mixtures.
5. Verify the pressure–volume–temperature relationship of gases and determine the gas constant experimentally.
6. Determine the composition, partial pressures, average molecular weight, and density of gaseous mixtures using Dalton's Law and Amagat's Law.
7. Measure dry-bulb and wet-bulb temperatures and determine relative humidity, humidity ratio, dew point, and degree of saturation using psychrometric charts.
Evaluation Method:
<table>
<tr><th>Sr. No.</th><th>Evaluation Methods</th><th>SEE</th><th>CCE</th></tr>
<tr><td>1</td><td>Industrial Calculation Case Study: Students will solve industrial case studies related to gas laws, humidity, concentration, and unit conversion calculations used in chemical industries.</td><td>20</td><td></td></tr>
<tr><td>2</td><td>Concept Presentation: Applications of Chemical Calculations: Students will prepare charts/models/PPT presentations explaining the practical applications of gas laws, humidity, and concentration measurements in industries.</td><td></td><td>10</td></tr>
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</td><td>12</td><td>20 %</td></tr>
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		Total	20	10	

Examination Style:

Industrial Calculation Case Study (20 Marks)

Students will analyze industrial process situations and perform calculations related to gaseous mixtures, humidity, concentration expressions, and dimensional analysis. Viva questions based on industrial applications and engineering significance will also be included.

Applications of Chemical Calculations (10 Marks)

Students shall prepare and present charts, posters, models, or PPTs explaining real industrial applications of chemical calculations in fertilizer, petrochemical, and chemical processing industries, limitations, and labeled diagrams wherever necessary.

2	**Material Balance without Chemical Reactions** **Theory Topics:** Introduction to material balance, process flow sheet, process flow diagram, block diagram and P&ID. Material balance problems without chemical reactions in unit operations. Material balance of unsteady state operations. Material balance with and without recycle, bypass and purge streams. **Practical:** 8. Draw and interpret BFD, PFD, and P&ID for a simple chemical process such as mixing, heating, or distillation. 9. Perform material balance calculations for mixing, splitting, and separation operations under steady-state conditions. 10. Solve material balance problems involving evaporators, dryers, filters, crystallizers, and distillation columns without chemical reactions. 11. Determine accumulation, input, output, and storage of material in batch tanks and filling/emptying processes under unsteady-state conditions. 12. Perform material balance calculations for process flow sheets involving recycle, bypass, and purge streams and determine stream flow rates and compositions. 13. Develop a simple process flow sheet, perform material balance calculations, and compare simulation results with manual calculations. **Evaluation Method:**	12	20 %

Sr. No.	Evaluation Methods	SEE	CCE
1	**Process Flow Sheet Problem Solving:** Students will analyze process flow diagrams and perform material balance calculations involving recycle, bypass,	20	

		and purge streams.			
	2	**Flow Diagram Activity:** *Industrial Plant Layout Study*: Students will prepare and explain block diagrams, PFDs, and P&ID layouts of chemical plants.		10	
		Total	**20**	**10**	

Examination Style:

Process Flow Sheet Problem Solving (20 Marks)

Students will solve industrial material balance problems using process flow sheets and process block diagrams for unit operations without chemical reactions. Viva questions related to recycle, bypass, purge operations, and process symbols will also be included.

Industrial Plant Layout Study (10 Marks)

Students shall prepare industrial process flow diagrams, block diagrams, or P&ID charts for selected chemical industries and explain material movement and unit operations involved.

3	**Material Balance with Chemical Reactions** **Theory Topics:** Concept of limiting and excess reactants, percentage conversion, selectivity and yield. Material balance involving chemical reactions with reference to fertilizer, petrochemical, dyestuff and electrochemical industries. Complex material balance calculations. **Practical:** 14. Perform material balance calculations to identify the limiting and excess reactants in chemical reactions. 15. Determine percentage conversion, product yield, and selectivity for single and multiple chemical reactions using experimental or given process data. 16. Perform material balance calculations for the production of ammonia or urea, considering reactants, products, and recycle streams. 17. Solve material balance problems for petrochemical processes such as steam cracking, methanol production, or ethylene manufacturing. 18. Carry out material balance calculations for a dye manufacturing process, including reactants, products, by-products, and process losses. 19. Perform material balance calculations for electrochemical operations such as chlor-alkali production, electrolysis of water, or electroplating using Faraday's law.	12	20%

20. Solve comprehensive material balance problems involving multiple reactions, recycle, bypass, purge streams, and process flow diagrams for industrial chemical processes.

Evaluation Method:

Sr. No.	Evaluation Methods	SEE	CCE
1	**Reaction Engineering Case Study:** Students will perform stoichiometric and material balance calculations using industrial reaction process data.	20	
2	**Industry Process Presentation:** *Chemical Reaction Systems:* Students will prepare presentations or charts explaining reaction processes used in fertilizer, petrochemical, and dye industries.		10
	Total	**20**	**10**

Examination Style:

Reaction Engineering Case Study (20 Marks)

Students will solve industrial reaction-based problems involving limiting reactants, excess reactants, conversion, yield, and selectivity calculations. Viva questions related to industrial reaction systems and stoichiometry will also be included.

Chemical Reaction Systems (10 Marks)

Students shall prepare a technical presentation, process chart, or industrial case analysis explaining reaction operations and material balance calculations used in industrial plants.

4

Energy Balance and Stoichiometry:

Theory Topics:

Heat capacity of gases, liquids and solids. Sensible heat changes in liquids and gases, enthalpy changes during phase transformation and chemical reactions, Hess's Law, heat of solution and adiabatic reactions. Stoichiometry and unit operations such as distillation, absorption, stripping, extraction, leaching, crystallization, psychrometric operations, drying and evaporation.

12

20%

Practical:

21. Determine the specific heat capacity of solid and liquid samples using the method of mixtures (calorimetry).
22. Calculate sensible heat requirements for heating and cooling gases and liquids using heat capacity data.

23. Measure the heat of solution of a salt in water and calculate the enthalpy change of dissolution.
24. Determine the enthalpy change of a reaction experimentally and verify Hess's Law using calorimetric measurements.
25. Perform energy balance calculations for unit operations such as distillation, evaporation, drying, and crystallization under steady-state conditions.
26. Perform stoichiometric calculations involving reactants, products, limiting reactants, excess reactants, conversion, yield, and selectivity for industrial processes.
27. Determine humidity, humid heat, dew point, adiabatic saturation temperature, and heat requirements for drying operations using psychrometric charts.

Evaluation Method:

Sr. No.	Evaluation Methods	SEE	CCE
1	**Energy Analysis Activity:** Students will solve industrial energy balance problems related to heating, cooling, drying, evaporation, and psychometric operations.	20	
2	**Unit Operation Demonstration:** *Industrial Heat Transfer Processes:* Students will prepare working models, flow charts, or presentations on distillation, drying, evaporation, and crystallization systems.		10
	Total	**20**	**10**

Examination Style:

Energy Analysis Activity (20 Marks)

Students will analyze industrial heat balance situations and solve numerical problems related to enthalpy, sensible heat, psychrometric operations, and drying calculations. Viva questions related to energy balance and industrial unit operations will also be included.

Industrial Heat Transfer Processes (10 Marks)

Students shall prepare models, process charts, or presentations explaining industrial unit operations such as distillation, absorption, evaporation, crystallization, and drying.

5	**Fuel, Combustion and Industrial Applications** **Theory Topics:** Types of fuels and calorific values. Combustion calculations for coal, liquid and gaseous fuels. Dulong Formula and Calderwood Equation. Proximate and ultimate analysis, combustion calculations, theoretical flame temperature, air requirement and flue gases. Boiler material and energy balance calculations with industrial applications.	12	20 %

Practical:

28. Determine the calorific value of a fuel using a Bomb Calorimeter and calculate GCV and NCV.
29. Determine the moisture content, volatile matter, ash content, and fixed carbon of a coal sample.
30. Calculate the elemental composition of fuels and determine the theoretical oxygen and air requirements for complete combustion.
31. Perform combustion calculations to determine excess air, flue gas composition, and combustion efficiency for different types of fuels.
32. Estimate the calorific value of fuels using Dulong Formula and Calderwood Equation and compare the results with experimental values.
33. Calculate the adiabatic flame temperature and determine the composition of combustion products under different operating conditions.
34. Perform material and energy balance calculations for an industrial boiler, including fuel consumption, steam generation, boiler efficiency, and heat losses.

Evaluation Method:

Sr. No.	Evaluation Methods	SEE	CCE
1	**Combustion and Boiler Analysis:** Students will perform industrial combustion calculations and analyze fuel efficiency, air requirement, and flue gas composition.	20	
2	**Industrial Fuel System Study:** *Boiler and Furnace Applications:* Students will prepare charts, presentations, or reports on industrial fuel systems, boilers, and combustion equipment.		10
	Total	**20**	**10**

Examination Style:

Combustion and Boiler Analysis (20 Marks)

Students will solve industrial combustion and fuel analysis problems related to calorific value, air-fuel ratio, flue gas analysis, and boiler efficiency. Viva questions related to combustion systems and industrial fuel applications will also be included.

Boiler and Furnace Applications (10 Marks)

Students shall prepare industrial case studies, process charts, or presentations explaining boiler systems, combustion equipment, fuel handling systems, and flue gas treatment methods used in industries.

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 %	20%	15%	25%	15%	25%	00%

Course Outcome:

After learning the course, the students should be able to:	
CO1	Apply the concepts of units, dimensions, gas laws, and concentration terms used in chemical engineering calculations.
CO2	Perform material balance calculations for steady-state and unsteady-state systems with recycle, bypass, and purge operations.
CO3	Solve material balance problems involving chemical reactions using concepts of limiting reactants, conversion, yield, and selectivity.
CO4	Analyze energy balance and stoichiometric calculations involved in unit operations such as distillation, drying, evaporation, and combustion processes.
CO5	Interpret process flow sheets and apply fuel and combustion calculations in fertilizer, petrochemical, dye, and specialty chemical industries.

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: Units, Dimensions and Basic Chemical Calculations

Industrial Calculation Case Study: (20 Marks)		
Criteria	**Description**	**Marks**
Unit Conversion	Correct conversion of engineering units and application of dimensional consistency in chemical calculations.	5
Gas Law Application	Proper solving of industrial problems related to gaseous mixtures, ideal gas laws, humidity, and saturation.	5
Calculations	Accurate calculation of concentration terms, average molecular weight, density, and humidity-related numerical problems.	5
Observation & Viva	Proper interpretation of industrial case study data and answering viva questions related to chemical calculations and applications.	5
	Total	20

Module–2: Material Balance without Chemical Reactions

Process Flow Sheet Problem Solving: (20 Marks)		
Criteria	**Description**	**Marks**
Flow Sheet Understanding	Correct identification and interpretation of process flow diagrams, block diagrams, and P&ID symbols.	5
Material Balance Setup	Proper formulation of material balance equations for unit operations without chemical reactions.	5
Calculations	Accurate solution of recycle, bypass, purge, and unsteady-state material balance problems.	5
Observation & Viva	Proper explanation of process calculations and answering viva questions related to industrial material balance systems.	5
	Total	20

Module–3: Material Balance with Chemical Reactions

Reaction Engineering Case Study: (20 Marks)		
Criteria	**Description**	**Marks**
Reaction Analysis	Correct identification of limiting reactants, excess reactants, conversion, yield, and selectivity in industrial reactions.	5
Stoichiometric Setup	Proper formulation of stoichiometric relationships and reaction balance equations.	5
Calculations	Accurate material balance calculations involving chemical reactions using industrial process data.	5
Observation & Viva	Proper interpretation of reaction process data and answering viva questions related to stoichiometry and industrial reaction systems.	5
	Total	20

Module–4: Energy Balance and Stoichiometry

Energy Analysis Activity: (20 Marks)		
Criteria	**Description**	**Marks**
Heat Balance Analysis	Proper understanding of heat capacity, sensible heat, latent heat, and enthalpy changes in industrial operations.	5
Process Understanding	Correct analysis of energy transfer in drying, evaporation, distillation, and psychometric operations.	5
Calculations	Accurate solution of energy balance and enthalpy-related numerical problems using industrial data.	5
Observation & Viva	Proper interpretation of energy balance results and answering viva questions related to unit operations and heat transfer processes.	5
	Total	20

Module–5: Fuel, Combustion and Industrial Applications

Combustion and Boiler Analysis: (20 Marks)		
Criteria	**Description**	**Marks**
Fuel Analysis	Correct understanding of fuel properties, calorific value, proximate analysis, and ultimate analysis.	5
Combustion Calculations	Proper calculation of air requirement, flue gas composition, and combustion efficiency.	5
Boiler Performance	Accurate analysis of boiler material and energy balance calculations using industrial examples.	5
Observation & Viva	Proper interpretation of combustion system performance and answering viva questions related to fuels and boilers.	5
	Total	20