PRAVARA RURAL EDUCATION SOCIETY
PRAVARA RURAL ENGINEERING COLLEGE
LONI

Chemical Engineering
Academic Book

T.E. Chemical

(2019 Pattern) (Semester-II)

Content:

Vision and Mission of the institute

Vision

Enrich the youth with skills and values to enable them to contribute in the development of society; nationally and globally.

Mission

To provide quality technical education through effective teaching-learning and research to foster the youth with skills and values to make them capable of delivering significant contribution in local to global development.

Vision and Mission of the Department

Vision

The department is committed to provide quality technical education to students in the field of Chemical engineering to meet the global expectations of industry and society.

Mission

To prepare the students to hold authority in Chemical Engineering, pursue their education through advanced study & endow to the betterment of society.

PROGRAM OUTCOMES

Engineering Graduates will be able to:

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO1: Apply the knowledge of basic science and basic courses of the Chemical Engineering In industry.

PSO2: Acquire the skills of design and analysis of the Chemical process or system to meet the desired needs within the practical limits.

PSO3: Ability to use the innovative techniques, skills and modern engineering tools necessary to industry and society.

Program Educational Objectives (PEOs)

Graduates would demonstrate ability to,

- **PEO1:** To impart strong knowledge of fundamentals to the students so that they can be good practicing engineers in Chemical Engineering.
- **PEO2:** To teach basic concepts, knowledge through experimentation, scientific literature & prediction of system behavior by models & simulations.
- **PEO3:** To develop overall personality, inculcate team spirit & capability of shouldering responsibility of nation building

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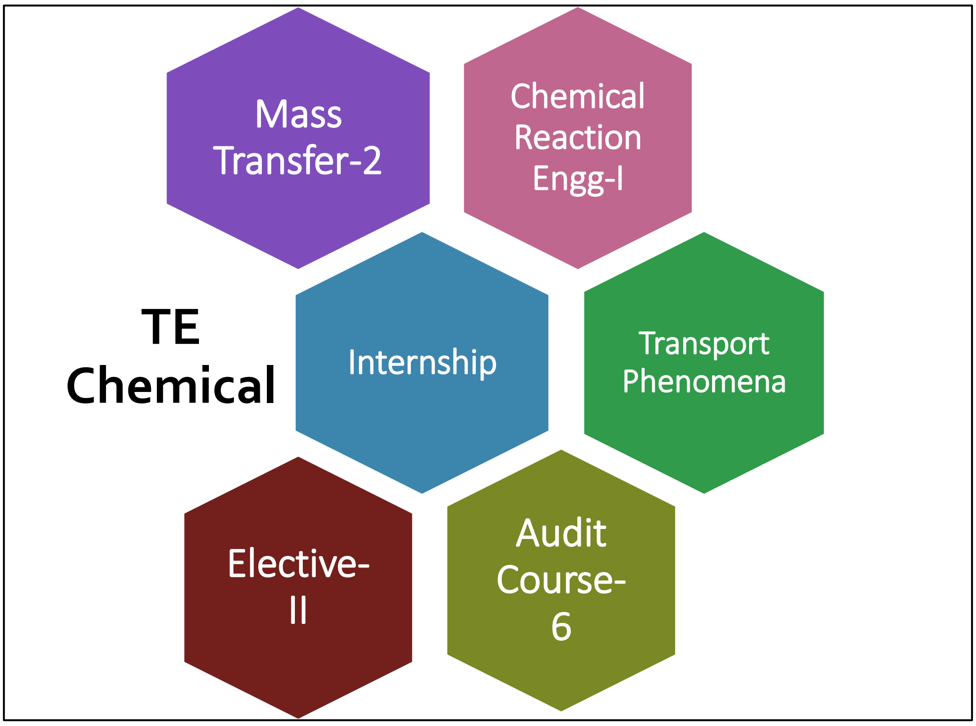
Syllabus Structure

Course code	Course Title	Total number of contact hours				Total Credits
		Lecture (L)	Tutorial (T)	Practical (p)	Total	
Third Year						
309348	Chemical Reaction Engineering I	03	--	04	07	05
309349	Mass Transfer II	03	--	04	07	05
309350	Transport Phenomena	03	02	--	05	04
309351	Elective-II	03	--	--	03	03
309352	Internship	--	04	--	04	04
	Audit Course -6	-	-	-	-	--



ACADEMIC CALENDER

Regular Activity

- HOD, Staff meeting – Twice Every Month 2nd and 4th Saturday
- Submission of monthly student Class Attendance and list of defaulter students to Dean Academic on first working day of every month
- Conduction of Test I, II and III (FE TO BE)

  Test – I - After 40 Days of Commencement of Teaching
  Test –II - After 70 Day of Commencement of Teaching
  Test – III - Before Conclusion of Semester
- Students feedback Report (FE,SE,TE and BE) submission to Principal (Twice in semester – 1st at mid semester and 2nd before the end of semester)
- Parent meets report submission by department to Principal at the mid semester.
- One week Soft skill training programme (FE,SE,TE and BE)
- Department Level Research meet of all department on 4th Saturday of every month
- Minimum one Industrial Visit per class per semester. (FE,SE,TE and BE)
- Organization of National/International level Seminar/Workshop/Conference by Departmental once in a semester.

Course: 01

CHEMICAL REACTION ENGINEERING –I

(309348)

[Theory & Practical]

Course Syllabus

CHEMICAL REACTION ENGINEERING –I (309348)

Unit 1: Kinetics of Homogeneous Reactions 7 Hrs
Defining a rate equation and its representation, single and multiple reactions, elementary and non elementary reactions, molecularity and order of reactions, kinetic models for non-elementary reactions, searching mechanism, rate controlling step.

Unit 2: Analysis and interpretation of Batch Reactor data 7 Hrs
Constant volume batch reactor, integral and differential methods of analysis, variable volume batch

Unit 3: Reactor Design 7 Hrs
Introduction, conversion of mass in reactors, performance equation for ideal stirred tank reactor, tubular flow reactor, batch reactor, space time and space velocity. Isothermal Reactors for single Reactions: Batch reactor, mixed versus plug flow reactors, second order reactions, graphical comparison, multiple reactor system, plug flow reactors in series and in parallel, equal size mixed reactors in series, reactors of different types in series, recycle reaction (flow, batch), auto-catalytic reactions, non- steady flow semi-batch reactors.

Unit 4: Multiple reactions 7 Hrs
Parallel and series reactions, performance of various ideal reactors, qualitative and quantitative discussion for multiple reactions, instantaneous and overall fractional yield.

Unit 5: Temperature and pressure effects 7 Hrs
Temperature dependency from Arrhenius law, thermodynamics, collision theory, transition state theory, comparison of theories, rate of reactions predicted by theories, single reactions: heat of reaction from thermodynamics, equilibrium constants from thermodynamics, graphical design procedure, heat effects, adiabatic operations, non adiabatic operations.

Unit 6: Deviations from Ideal Reactor 7 Hrs
Self mixing of a single fluid & two miscible units, Residence time distribution, F,C,E, curves and relation between them. Models for non-ideal reactions, dispersion model, tanks in series model, segregated flow model.

References:

1. Chemical Reaction Engineering: Levenspile O.
2. Chemical Engineering Kinetics: Smith J.,
3. Elements of Chemical Reaction Engineering: H. Scott, Fogler.

TE Chemical 309348: CHEMICAL REACTION ENGINEERING –I

Teaching Scheme: Lectures : 3 Hours / Week Practical : 4 Hours / Week	**Examination Scheme:** In Semester: 30 End Semester: 70 Practical: 50 TW: 25 **Total: 175 Credits:5**

Course Outcomes (CO's) : CHEMICAL REACTION ENGINEERING –I

After successful completion of this course, students will be able to:

Course Outcomes	Statements	Bloom's Taxonomy	
		Level	**Descriptor**
C348.1	Understand homogeneous reactions kinetics and mechanism.	3	Apply
C348.2	Analyze and Interpret the batch reactor data.	4	Analyze
C348.3	Design and develop the performance equation of homogeneous reactor.	6	Design
C348.4	Analyze and design the performance of parallel and series reactions.	4	Analyze
C348.5	Apply the effect of temperature and pressure on reaction kinetics.	3	Apply
C348.6	Design and develop of performance of Non ideal reactor.	6	Design

Mapping of Course Outcomes to Program Outcomes (POs) & Program Specific Outcomes (PSOs):

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) If there is no correlation, put “-“

COs	**PO**												**PROGRAM SPECIFIC OUTCOMES**		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO 1**	**PSO 2**	**PSO 3**
C348.1	3	2	2	2	2							1	3	3	2
C348.2	3	2	3	2	2							1	3	2	2
C348.3	2	3	3	2	2				1	1		1	2	2	2
C348.4	2	3	3	2	2				1	1		1	2	2	2
C348.5	2	3	3	2	2				1	1		1	2	2	2
C348.6	2	2	2	2	2				1	1		1	2	2	2
Total	14	15	16	12	12				4	4		6	14	13	12
Total Wt	18	18	18	18	18				12	12		18	18	18	18
% Mapping	77.78	83.33	88.89	66.67	66.67				33.33	33.33		33.33	77.78	72.22	66.67
Set	3	3	3	3	3				1	1		1	3	3	3

Levels: 3 for ≥60 ; 2 for < 60 ≥ 40; 1 for < 40

CO Assessment Tools

Course Outcomes (COs)	**Assessment Tools**							
	Continuous Internal Evaluation				**Semester End Exam (SEE) conducted by SPPU Pune**			
	T1	T2	Assignment	CIE-Pr	PR	TW	Insem	Endsem
C348.1	√		√		√	√	√	
C348.2	√		√		√	√	√	
C348.3		√	√	√	√	√		√
C348.4		√	√	√	√	√		√
C348.5			√	√	√	√		√
C348.6			√	√	√	√		√

Teaching Plan

CHEMICAL REACTION ENGINEERING –I (309348)

Teaching Scheme:	**Examination Scheme:**
Theory: 03 h/week	Insem: 30
	Endsem:70
Practical: 4 h / week	PR: 50 TW= 25
	Total=175 Credit =5

Lect. No.	Topics / Sub- Topics	CO Mapped
1.	PO,PSO,CO & Subject orientation	-
2.	**Kinetics Of Homogeneous Reactions**	1
3.	Defining A Rate Equation And Its Representation	1
4.	Single And Multiple Reactions	1
5.	Elementary And Non Elementary Reactions	1
6.	Molecularity And Order Of Reactions	1
7.	Kinetic Models For Non-Elementary Reactions,	1
8.	Searching Mechanism, Rate Controlling Step.	1
9.	Innovative teaching methods- Quiz	1
10.	**Analysis and interpretation of Batch Reactor data**	2
11.	Constant volume batch reactor	2
12.	integral methods of analysis	2
13.	differential methods of analysis	2
14.	Zero order reaction with numerical	2
15.	Variable volume batch	2
16.	First order reaction with numerical	2
17.	Innovative teaching methods- Cross word puzzle	2
18.	**Reactor Design** Conversion of mass in reactors	3
19.	Performance equation for ideal stirred tank reactor	3
20.	Performance Equation For Batch Reactor, Space Time And Space Velocity	3
21.	Plug Flow Reactors In Series And In Parallel, Equal Size Mixed Reactors In Series	3
22.	Reactors Of Different Types In Series	3
23.	Auto-Catalytic Reactions, Non- Steady Flow Semi-Batch Reactors.	3
24.	Innovative teaching methods- Flipped Class Room	3
25.	**Multiple Reactions**	4
26.	Parallel And Series Reactions	4
27.	Performance Of Various Ideal Reactors	4
28.	Qualitative And Quantitative Discussion For Multiple Reactions	4
29.	Instantaneous Fractional Yield	4
30.	Overall Fractional Yield With Numericals	4
31.	Innovative Teaching Methods- Flipped Class Room	4
32.	**Temperature And Pressure Effects**	5
33.	Temperature Dependency From Arrhenius law	5
34.	Heat Of Reaction From Thermodynamics	5
35.	Equilibrium Constants From Thermodynamics	5

36.	Graphical Design Procedure, Heat Effects	5
37.	Adiabatic Operations, Non Adiabatic Operations	5
38.	Innovative Teaching Methods- Flipped Class Room	5
39.	**Deviations From Ideal Reactor**	6
40.	Self Mixing Of A Single Fluid & Two Miscible Units	6
41.	Residence Time Distribution,.	6
42.	F,C,E, Curves And Relation Between them	6
43.	Models For Non-Ideal Reactions	6
44.	Dispersion Model	6
45.	Tanks In Series Model	6
46.	Segregated Flow Model	6
47.	Innovative Teaching Methods- Flipped Class Room	6
48.	University Question Paper	

Question Bank

CHEMICAL REACTION ENGINEERING –I (309348)

<table>
<tr><th>Que.</th><th>Unit-I</th><th>CO</th></tr>
<tr><td>1.</td><td>The activation energy of a bio molecular reaction is about 9150 cal/mol. How much faster is this reaction at 500K than at 400K?</td><td>1</td></tr>
<tr><td>2.</td><td>The reaction between CO and NO_2 at low temperature proceeds with a rate $-r_{O2}=k*[N O_2]^2$ Suggest mechanism.</td><td>1</td></tr>
<tr><td>3.</td><td>State various theories of temperature dependency and discuss any one in detail</td><td>1</td></tr>
<tr><td>4.</td><td>The rate constant of certain reaction are 1.6 x 10^{-3} and1.625 x 10^{-2} sec. at 10^0 C and 30^0 C.Calculate Activation energy. R= 1.987 cal/ mol.k</td><td>1</td></tr>
<tr><td>5.</td><td>For the order reaction, the following data is available.
Calculate Activation energy for the reaction. R= 8.314 J/mol.k
<table>
<tr><td>Temp .(k)</td><td>310</td><td>330</td></tr>
<tr><td>k $(sec)^{-1}$</td><td>0.000886</td><td>0.0139</td></tr>
</table></td><td>1</td></tr>
<tr><td>6.</td><td>Decomposition of Phospine follows the following stoichiometry
$4\ PH_3 \rightarrow P_4 + 6\ H_2$ if at an instant rate of decomposition of phosphine is 2x 10^{-4} kmol/ $m^{3.}$ Second .Calculate the Rate of formation of Phosphorous and Hydrogen</td><td>1</td></tr>
<tr><td>7.</td><td>On doubling the concentration of the reactants, the rate of reaction triples. Find reaction order.</td><td>1</td></tr>
<tr><td>8.</td><td>The rate equation for the decomposition of $2N_2O_5 \rightarrow 4NO_2 + O_2$ is $-r = k[N_2\ O_5]$.Propose suitable mechanism consistent with above rate equation.
Show that the following scheme is consistent with and can explain observed First order decomposition of N_2O_5
$$N_2O_5 \overset{k_1}{\rightarrow} NO_2 + NO_3^*$$
$$NO_2 + NO_3^* \overset{k_2}{\rightarrow} N_2O_5$$
$$NO_2 + NO_3^* \overset{k_3}{\rightarrow} NO_2 + O_2 + NO^*$$
$$NO^* + NO_3^* \overset{k_4}{\rightarrow} 2NO_2$$</td><td>1</td></tr>
</table>

9. Milk is pasteurized if it is heated to 63 ^{0}C for 30 min, but if it is heated to 74°C it only needs 15 sec. for the same result.Find the Activation energy of this sterilization process. R= 8.314 J/mol.k 1

10. Concentration rate data for the decomposition of $N_2 O_5$ at 70 ^{0} C is as follows 1

Conc. (mol/lit)	**0.113**	**0.080**	**0.056**	**0.040**
Rate (mol/lit.min)	0.039	0.028	0.020	0.014

$2\ N_2O_5 \rightarrow 4NO_2 + O_2$

Plot graph of rate against Concentration.

Find Rate expression and calculate rate constant.

11. The activation energy of a certain chemical reaction is 52.4 KJ / mol. If reaction is carried out at 28^0 C , for what temperature rise the reaction rate will double? (R= 8.314 J/mol.k) 1

12. The pyrolysis of ethane proceeds with an activation energy of about 75000 cal/mol. How much faster is the decomposition at 650^0 C than at 500^{0}C? R= 1.987 cal/mol.k 1

13. At 500k,the rate of a bimolecular reaction is ten times the rate at 400k. 1

Find Activation energy of this reaction from Arrhenius law. R= 1.987cal/mol. K

14. Experimental show that homogeneous decomposition of Ozone proceeds with a rate 1

a) What is the overall order of reaction?

b) Suggest two step mechanism to explain this rate.

15. The formation and decomposition of phosgene has been found to proceed as follows $CO + Cl_2 \overset{k_1 k_2}{\Longleftrightarrow} COCl_2$ 1

Forward reaction $r_{cocl_2=k_1[co]\left[[cl_2]^{3/2}\right]}$

Reverse reaction $-r_{cocl_2} = k_2[cocl_2]\left[[cl_2]^{1/2}\right]$

a) Are these expressions thermodynamically consistent?

b) Determine which of the following mechanism is consistent with these experimentally found rates.

16. Differentiate Elementary vs Non elementary Reaction 1

<table>
<tr><th>Que.</th><th>UNIT-II</th><th>CO</th></tr>
<tr><td>1.</td><td>In case of a first reaction, show that the times required for 75% conversion is double the time required for 50% conversion in a batch reactor.</td><td>2</td></tr>
<tr><td>2.</td><td>Apply Integral method of analyses and derive integrated expression for reaction A+B→ Product (consider $M \neq 1$)</td><td>2</td></tr>
<tr><td>3.</td><td>Calculate the first order rate constant for the disappearance of A as per the gas phase reaction A →1.6 R if the volume of reaction mixture, starting with pure A, increases by 50% in 4 minutes. The total pressure of the system remains constant at 1.2 atm and the temperature is 25 deg C.</td><td>2</td></tr>
<tr><td>4.</td><td>Discuss the Integral method of analyses for first order reactions in varying volume batch reactor.</td><td>2</td></tr>
<tr><td>5.</td><td>Derive performance equation of recycle reactor.</td><td>2</td></tr>
<tr><td>6.</td><td>Liquid A decompose by first order kinetics and in a batch reactor 50 % of A is converted in 5 min. run . How much longer would it take to reach 75% conversion?</td><td>2</td></tr>
<tr><td>7.</td><td>Show that the decomposition of N_2O_5 Type equation here.
at a 70 °C is first order reaction, Calculate valve of rate constant , reaction is
$$N_2O_5 \rightarrow N_2O_4 + \frac{1}{2}O_2$$
<table>
<tr><td>Time (min)</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>Conc. Of
$N_2 O_5$ (mol/lit)</td><td>0.16</td><td>0.113</td><td>0.08</td><td>0.056</td><td>0.040</td></tr>
</table></td><td>2</td></tr>
<tr><td>8.</td><td>In a Homogeneous isothermal polymerization 20 % of the monomer gets disappear in 34 min. For initial monomer concentration 0.04 and also for 0.8 mol/lit. What is expression for disappearance of the monomer?</td><td>2</td></tr>
<tr><td>9.</td><td>The rate constant of a zero order reaction is 0.2 mol/lit.hr
What will be the initial concentration of the reactant if, after an hour . its concentrations 0.05 mol/ lit?</td><td>2</td></tr>
<tr><td>10.</td><td>A reaction follows zero order kinetics. If the initial concentration is 1 mol/lit.
Calculate rate constant and time required for 95% conversion, if 80% conversion is reached in 45 minute.</td><td>2</td></tr>
</table>

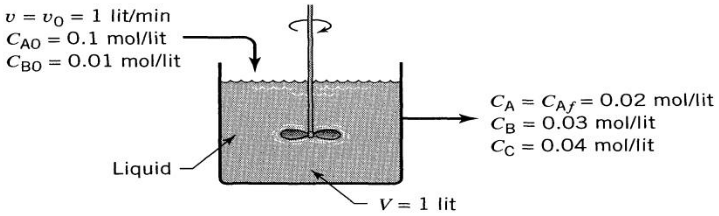
Que.	UNIT-III	CO
1.	Develop the performance equation of Plug flow reactor?	3
2.	The homogeneous gas decomposition of phosphine 4PH3(g) → P4(g) + 6H2(g) proceeds at 649 ^{0}C with the first order rate – r(PH3) = (10/hr) C(PH3) .What size of plug flow reactor operating at 649	3

^{0}C and 460 kPa can produce 80% conversion of a feed consisting of 40 mol of pure phosphine per hour?

3. Develop performance equation of mixed flow reactor with its graphically representation 3

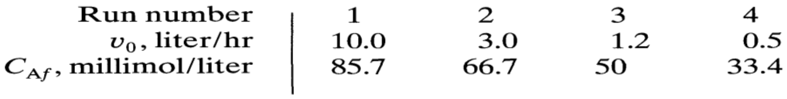
One liter per minute of liquid containing A and B (C_{A0} = 0.10 mol/liter, C_{B0} =0.01 mol per liter) flow into a **Mixed reactor** of volume V = 1 liter. The materials react in a complex manner for which the stoichiometry is unknown. The outlet stream from the reactor contains A, B, and C (C_{AF} = 0.02 mol/liter, C_{BF} = 0.03mol/liter, C_{CF} = 0.04 mol/liter), as shown in Fig. E5.1. 3

4. Find the rate of reaction of A, B, and C for the conditions within the reactor.



Pure gaseous reactant A (CAo = 100 millimol/liter) is fed at a steady rate into a Mixed flow reactor (V = 0.1 liter) where it dimerizes (2A R). For different gas feed rates the following data are obtained: 3

5.



Run number	1	2	3	4
v_0, liter/hr	10.0	3.0	1.2	0.5
C_{Af}, millimol/liter	85.7	66.7	50	33.4

Find a rate equation for this reaction

A vapour phase reaction A → 4R is to be carried out in PFR at 225^0 C. 3

6. Calculate the Space time needed for 75% conversion. Initial concentration of A is 0.08 mol/lit.

Que.	**UNIT-IV**	CO
1.	Explain instantaneous fractional yield and overall fractional yield with example.	4
2.	Discuss the contacting pattern for various reactant concentration combinations.	4
3.	Explain Energy balance equation for adiabatic operation graphically.	4
4.	Consider the parallel decomposition of A of different orders, $A \Rightarrow R$, $A \Rightarrow S$, $A \Rightarrow T$ where $r_R = 1$, $r_S = 2\ C_A$, $r_T = C_A^2$	4

R is the desired product, C_{AO}=2 mol/m^3

Determine the maximum concentration of desired product obtainable in mixed and plug flow reactor.

5.	Discuss product distribution for parallel reaction qualitatively	4

Que.	UNIT-V	CO
1.	Explain in detail the effect of temperature on equilibrium conversion of reactant at constant pressure.	5
2.	Discuss optimum temperature progression (OTP) needed for optimum reactor Performance.	5
3.	For aqueous reaction A <------> R, between the temperature range 0 to 100 ^{0}C, Determine the equilibrium conversion as a function of temperature in graphical form. What should be the maximum temperature so that the conversion of A achieved is 75 % or higher? For CR^0 = CA^0 = 1mol/ lit, ΔG^0, 298= -3375 cal/ mol, ΔHr, 298 = -18000 cal/mol	5
	What is Optimum Temperature propagation? Explain with respect to different types of reactors	

Que.	UNIT-VI	CO
1.	Explain E, F and C curve and find relationship between them.	6
2.	Discuss Dispersion model and tank in series model.	6
3.	Calculate the mean residence time and variance for a vessel from the following data	

t, min	0	1	2	3	4	5	6	7	8	9	106	12	14
E, min^{-1}	0	0.02	0.10	0.16	0.20	0.16	0.12	0.08	0.06	0.044	0.03	0.01	0

4.	The concentration readings in table represent a continuous response to a pulse input into a closed vessel which is to be used as a chemical reactor. Calculate the mean residence time of fluid in the vessel t, and tabulate and plot the exit age distribution E.	6

Time t, min	0	5	10	15	20	25	30	35
Tracer output concentration, C pulse gm/ liter fluid	0	3	5	5	4	2	1	0

CHEMICAL REACTION ENGINEERING –I (309348)

List of Practical

Sr. No.	Name of Experiment	CO Mapped
1	Continuous Stirred tank Reactor (CSTR)	CO3
2	Plug Flow Reactor (PFR)	CO3
3	Combined Flow Reactor	CO3
4	Isothermal Batch Reactor	CO3
5	Arrhenius Parameter	CO5
6	RTD Studies In CSTR	CO6
7	RTD Studies In PFR	CO6
8	RTD studies to determine E curve	CO6
9	CSTRs in series	CO3
10	Pseudo First Order reaction	CO1

Course: 02

Mass Transfer-II

(309349)

[Theory & Practical]

Course Syllabus

MASS TRANSFER –II (309349)

Unit 1: Distillation **7 Hrs**

Distillation principle, vapour-liquid equilibria for ideal and non-ideal systems, ideal solutions, positive and negative deviations from ideality, relative volatility, binary and multicomponent systems, methods of distillation - differential , flash, azeotropic, extractive, low pressure, steam distillation, batch rectification.

Unit 2: Continuous Rectification **7 Hrs**

Continuous rectification for binary system, multistage (tray) towers, packed towers for distillation, reboilers, distillation column internals, Lewis Sorrel, McCabe Thiele, and Ponchon-Savarit methods for multistage operations, tray efficiencies, concept of reflux, minimum reflux ratio, optimum reflux, total reflux, Fenske's equation, use of open steam, Partial and total Condensers, cold reflux, Fenske Underwood equation, concept of multi component distillation.

Unit 3: Liquid-Liquid Extraction **7 Hrs**

Ternary liquid equilibria, single stage extraction, multistage crosscurrent, countercurrent and cocurrent extraction, calculations based on triangular diagrams, x – y coordinates and solvent free basis, Continuous counter current extraction with reflux, total reflux, stage efficiency, continuous contact extraction in packed towers, HTU and NTU concept, types of extractors – stage type and differential type.

Unit 4: Solid-Liquid Extraction (Leaching) **7 Hrs**

Leaching equipment-continuous counter current leaching, ideal stage equilibrium, operating time, constant and variable underflow, number of ideal stages, stage efficiencies, calculation of single stage and multistage leaching processes.

Unit 5: Adsorption and Ion Exchange **7 Hrs**

Adsorption – Basic principle and equilibria in adsorption, types of adsorption-physical and chemical adsorption, break through curve, adsorption hysteresis, calculations of single stage, multistage adsorption, rate of adsorption in fixed bed, adsorption Isotherms-Langmuir and Freundlich, Introduction to pressure swing adsorption (PSA), and temperature swing adsorption (TSA). Ion Exchange: principles of ion exchange, techniques and applications, equilibria and rate of ion exchange, equipment's.

Unit 6: Crystallization & Novel Techniques **7 Hrs**

Principle of crystallization, rate of crystal growth, size distribution, solubility curves, Mier's supersaturation theory, material balance, enthalpy balances, calculation of yield, equipments.

Introduction to membrane separation techniques: ultra-filtration, nanofiltration, reverse osmosis, types of membranes and membrane modules, fluxes and driving forces in membrane separation processes.

References:

1. Treybal R.E. “Mass Transfer Operation”
2. Richardson J. F. and Coulson J.M. “Chemical Engineering”, Vol. I , II
3. McCabe and Smith, ‘Unit Operations in Chemical Engineering” 4. Henley E. J. and Seader H.K. “Stage wise Process Design”, McGraw Hill
5. Smith B.D., “Design of Equilibrium Stage Process”.
6. Foust A.S., “Principles of Unit Operations”
7. King C. J. “Separation Processes”, McGraw Hill A.L. Lyderson, “Mass Transfer in Engineering Practices”, John Wiley

Chemical Engineering Department

309349: Mass Transfer-II

Teaching Scheme: Lectures :3 Hours / Week Practical: 4 h / week	**Examination Scheme:** In Semester: 30 End Semester: 70 PR: 50 TW:50 **Total: 200** **Credits: 3+2**

Course Outcomes (CO's) : Mass Transfer-II

After successful completion of this course, students will be able to:

Course Outcomes	Statements	Bloom's Taxonomy	
		Level	Descriptor
C349.1	Analyse Vapour-liquid equilibrium data for ideal and non-ideal system and derive equations to find out compositions of distillation products.	**4**	**Analyse**
C349.2	Evaluate the number of stages required for desired separation of components from its mixture on basis of volatility and can predict efficiency of distillation column	**5**	**Evaluate**
C349.3	Develop equilibrium relationship between the multicomponent systems and design the equipment for extraction of component from miscible liquids.	**3**	**Understand**
C349.4	Evaluate the number of stages required to separate desired liquid product from solid and can design leaching equipment	**4**	**Analyse**
C349.5	Understand fundamentals of adsorption and ion exchange via. Equilibrium properties, transport properties and Determine kinetics of adsorption mechanism.	**3**	**Understand**
C349.6	Evaluate material and energy required to perform crystallization and can understand the various membrane separation processes and background of nucleation, crystal growth in crystallization mechanism.	**5**	**Evaluate**

Mapping of Course Outcomes to Program Outcomes (POs) & Program Specific Outcomes PSOs

COs	PROGRAM OUTCOMES												PSO	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
C349.1	3	3	3	2	2	--	--	--	--	2	--	2	2	3
C349.2	2	2	2	3	3	--	--	--	--	1	--	2	3	2
C349.3	2	3	3	2	2	--	--	--	--	2	--	2	2	2
C349.4	2	2	3	--	--	--	--	--	--	1	--	2	2	2
C349.5	2	2	2	3	3	--	--	--	--	3	--	2	3	--
C349.6	2	2	1	2	2	--	--	--	--	2	--	2	1	2
Total	13	14	14	12	12	--	--	--	--	11	--	12	13	11
Total Wt	18	18	18	15	15	--	--	--	--	18	--	18	18	15
% Mapping	72.22	77.78	77.78	80.00	80.00	--	--	--	--	61.11	--	66.67	72.22	73.33
C349	3	3	3	3	3	--	--	--	--	3	--	3	3	3

CO Assessment Tools

Course Outcomes (COs)	Assessment Tools								
	Continuous Internal Evaluation					**Semester End Exam (SEE) conducted by SPPU Pune**			
	T1	T2	T3	Assignment	CIE-Pr	PR	TW	Insem	Endsem
C349.1	√			√	√	√	√	√	
C349.2	√			√	√	√	√	√	
C349.3		√		√	√	√	√		√
C349.4		√		√	√	√	√		√
C349.5			√	√	√	√	√		√
C349.6			√	√	√	√	√		√

Chemical Engineering Department

Teaching Plan

Mass Transfer-II (309349)

Lect. No.	Topics / Sub- Topics	CO Mapped
1	PO,PSO,CO & Subject orientation	-
2	**Unit-1 Distillation** Introduction and basic principle	1
3	Vapour-liquid equilibria for ideal and non-ideal systems	1
4	Ideal solutions, positive and negative deviations from ideality	1
5	Relative volatility, binary and multicomponent systems,	1
6	Differential and flash distillation.	1
7	Azeotropic and Extractive distillation.	1
8	**Unit-2: Continuous rectification** Batch rectification.	2
9	Continuous rectification for binary system.	2
10	Multistage (tray) towers, Packed tower for distillation.	2
11	Reboilers and distillation column internals.	2
12	Lewis Sorel method and problems.	2
13	McCabe Thiele method and problems.	2
14	Ponchon-Savarit method and problems.	2
15	Tray efficiencies, Concept of reflux.	2
16	Minimum reflux, Optimum reflux and Total reflux ratio.	2
17	Fenske's equation, use of open steam, Partial and total Condensers, cold reflux	2
18	Fenske-Underwood equation, concept of multi component distillation.	2
19	**Unit-3: Liquid-Liquid Extraction** Ternary liquid equilibria.	3
20	Single stage extraction and problems.	3
21	Multistage crosscurrent Extraction and problems.	3
22	Countercurrent and cocurrent extraction.	3
23	Study of triangular diagrams to calculate compositions.	3
24	x – y coordinates and solvent free basis method to solve extraction problems.	3
25	Brief study of Continuous counter current extraction with reflux.	3
26	Total reflux and stage efficiency of extraction.	3
27	Continuous contact extraction in packed towers and its HTU and NTU concept.	3
28	Study of stage and differential type extractors.	3
29	**Unit 4: Solid-Liquid Extraction (Leaching)**	4

	Equilibrium concept of ideal stage leaching.	
30	Constant and variable underflow, operating time.	4
31	Methods to calculate number of ideal stages.	4
32	Stage Efficiencies and problems.	4
33	Calculation of single stage and multistage leaching processes.	4
34	Leaching equipment-continuous counter current leaching	4
35	Leaching equipment-continuous counter current leaching	4
36	Problems.	4
37	**Unit 5: Adsorption and Ion Exchange** Definition and basic principles of adsorption	5
38	Physical and chemical adsorption.	5
39	Break through curve and adsorption hysteresis.	5
40	Single and multistage adsorption calculations.	5
41	Langmuir and Freundlich adsorption isotherm	5
42	Pressure swing adsorption (PSA), and Temperature swing adsorption (TSA).	5
43	Basic principles and Equillibria concept of Ion Exchange	5
44	Techniques and applications of Ion Exchange	5
45	Equipment's used and Problems.	5
46	**Unit 6: Crystallization & Novel Techniques** Basic principles and steps involved in crystallization.	6
47	Solubility curve and methods of super saturation	6
48	Mier's super saturation theory	6
49	material and energy balances of crystallization	6
50	Ultra filtration, Nano filtration, Reverse osmosis.	6
51	Types of membranes and membrane modules	6
52	Fluxes and driving forces in membrane separation processes.	6

Question Bank

Mass Transfer-II (309349)

Q.1 A liquid mixture containing 40 wt% benzene and 60 wt % toluene is subjected to flash distillation at pressure 101.325 Kpa to vaporize 50 % of feed. What will be the equilibrium composition of vapor and liquid?

X	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Y	0.13	0.21	0.375	0.5	0.6	0.7	0.77	0.83	0.9	0.95	1.0

Q.2 A liquid mixture is subjected to differential distillation containing 50 mole % n-heptane and 50 mole % n-octanes at atmospheric pressure until the residual liquid contains 35 mole % n-heptane. Find out the % of feed left over as residue

X	0.5	0.46	0.42	0.38	0.34	0.32
Y	0.689	0.648	0.608	0.567	0.523	0.49

Q.3 A liquid mixture containing 45 mol % benzene and 55 mole % toluene is separated to give an overhead product of 95 mole % benzene and the bottom product containing 5 mole % benzene . The feed is at its boiling point. Using Mc-Cabe Thiele method, find Minimum reflux ratio and no of theoretical plates required.

X	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Y	0.13	0.21	0.375	0.5	0.6	0.7	0.77	0.83	0.9	0.95	1.0

Q.4 A saturated liquid mixture containing 60 mole % benzene and 40 mole % toluene is to be separated continuously in to a distillate product containing 90 mole % benzene and the bottom product containing 5 mole % benzene. The fractional distillation column will operate at 1 atm. The reflux ratio is 2. How many theoretical plates must be the columns have if the feed is introduced in to the eight plates?

X	0	0.017	0.075	0.13	0.211	0.288	0.37	0.411	0.581	0.78	1.0
Y	0	0.039	0.161	0.261	0.393	0.496	0.591	0.632	0.777	0.9	1.0

Q.5 In the system of chlorobenzene and water, if steam is blown in the still containing a mixture of these two components and the total pressure is 130 mmHg, estimate the temperature of boiling and the composition of distillate, the two components are immiscible in the liquid. Vapor pressure of chlorobenzene and water are:

Vapor Pressure, mmHg	100	50	30	26
Temprature ^{o}C, chlorobenzene	70.4	53.7	42.7	34.5
Temprature ^{o}C, water	51.7	38.5	29.9	22.5

Q.6 Partially vaporized feed of composition 42 mole% heptanes and 58 mole% ethyl benzene is to be fractionated at 1 atm to give distillate containing 95 mole % heptanes and bottom containing 95 mole % ethyl benzene. The feed is 40% liquid and 60% vapor (all in mole basis) **calculate**

a) Value of q and slope of q-line,
b) min. reflux ratio,

c) Number of plates at R = 2.5, the equilibrium data is:

X	0	0.08	0.25	0.485	0.79	1.0
Y	0	0.23	0.514	0.730	0.904	1.0

Q.7 A binary mixture of methanol 30 wt% and ethanol 70 wt% is to be separated by fractionation to obtain each of 95 wt % purity. Calculate the min reflux if the feed is 30 % vaporized. Also calculate actual number of plates if a reflux ratio of twice the minimum is used when the overall plate efficiency is 60%. The data given is as follows:

Temprature, ^{0}C	64	67	70	73	76	78
P^0,(CH_3OH)	760	820	920	1020	1150	1260
P^0,(C_2H_5OH)	420	430	470	610	690	760

Q.8 1000 kg/hr of mixture containing 42 mole percent heptane and 58 mole percent ethyl benzene is to be fractioned to a distillate containing 97 mole percent and residue containing 99 mole percent ethyl benzene using a total condenser and feed at its saturated liquid condition, The enthalpy-concentration data for the heptane-ethyl benzene at 1 atm pressure are as follows:

X heptane	0	0.08	0.18	0.25	0.49	0.65	0.79	0.91	1.0
Y heptane	0	0.28	0.43	0.51	0.73	0.83	0.90	0.96	1.0

H_1 (kJ/kmol)x10^3	24.3	24.1	23.2	22.8	22.05	21.75	21.7	21.6	21.4
H_0 (kJ/kmol)x10^3	61.2	59.6	58.5	58.1	56.5	55.2	54.4	53.8	53.3

Calculate the following:

1. Minimum reflux ratio
2. Number of stages at reflux of 2.5
3. Condenser duty
4. Reboiler duty (use ponchon savarit method)

Q.9 A liquid mixture containing 1200 gmole of mixture containing 30 mole% naphthalene and 70 mole% dipropylene glycol is subjected to differential distillation at pressure 100 mmHg and final distillate contain 55 mole% of feed solution the VLE data are:

X	8.4	11.6	28.0	50.6	68.7	80.6	88
Y	22.3	41.1	62.9	74.8	80.2	84.4	88

Q.10. A feed solution contains 100 moles of benzene –toluene mixture having 70 mole % benzene. One third of feed is vaporized. The total pressure is 1 atm. Calculate distillate composition and bottom composition for flash distillation if relative volatility is 2.50

Q.11. A liquid mixture containing 45 mol% benzene and 55mole% toluene is separated to give an overhead product of 95 mole % benzene and the bottom product containing 5 mole% benzene . The feed is at its boiling point. Using Mc-Cabe Thiele method find Minimum reflux ratio and no of theoretical plates required. Use equilibrium data of Q.3

Q.12. 100 moles of benzene (A) and toluene (B) mixture containing 50 % mole of benzene is subjected to differential distillation at atmospheric pressure till the composition of the benzene in the residue is 33 %. Calculate the total moles of the mixture distilled. Average relative volatility is 2.16.

Q.13. A liquid mixture containing 50 mole % heptanes (A) and octane (B) is to be continuously flash vapoursied at 1 standard atmosphere to vaporize 60 mole % of feed . What will be the compositions of the vapor and liquid in the separator for an equilibrium stage?

t °C	98.5	105	110	115	120	125.5
V.P. of A, mm Hg.	760	940	1050	1200	1350	1540
V.P of B, mm Hg.	333	417	484	561	650	760

Q.14. A mixture of 35 mole % of A and 65 mole % 0f B is to be separated in fractionating column. The concentration of A in the distillate is 93 mole % and 96 % 0f all product A is in the distillate. The feed is half vapor and the reflux ratio is to be 4.0. The relative volatility of A to B is 2.0. Calculate the number of theoretical plates in the column and location of feed plate.

Q.15. A continuous fractionating column is to design to separate 350 gm-mole per minute of binary mixture containing 40 weight % of benzene and 60 weight% of toluene. The top product contains 97 weight % of benzene and bottom product contains 98 weight % toluene. A reflux ratio of 3.5 moles to 1 mole of product is to be used. The feed is liquid at its boiling point.

a) Determine the number of ideal plates

b) Calculate the moles of overhead and bottom product

Equilibrium data:

X	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Y	0.185	0.36	0.50	0.61	0.70	0.78	0.84	0.90	0.95	1.0

Q.16. A mixture of benzene and toluene containing 40 mole % of benzene is to be separated to give a product of 90 mole % benzene using average of 2.4 for the volatility of benzene relative to toluene. Calculate the number of theoretical plates required at total reflux. Also calculate the minimum reflux ratio if the feed is liquid at its bubble point.

Q.17. 1000 Kg moles per hour of an ethanol-propanol mixture containing 65 mole % ethanol is to be separated in continuous plate column operating at 1 atm total pressure desired terminal compositions in units of mole fraction of ethanol are X_d = 0.92 and X_w =0.07 . the feed is saturated vapor and total condenser is used. When the reflux flow rate is 4 times the amount of top product find the number of theoretical plates required for the separation. The relative volatility of ethanol- propanol mixture may be taken as 2.10.

Q.18. Nicotine in water solution is to be extracted using kerosene in 5 cross- current stages using 30 Kg of solvent in each stage. For 100 Kg feed is to be treated, find the percentage of extraction and concentration of final raffinate if the equilibrium relation is X= 1.11 Y where, X= Kg Nicotine / Kg water , Y= Kg Nicotine / Kg kerosene.

Q.19. A 2500 Kg batch of pyridine – water solution, 50 % pyridine is to be extracted with chlorobenzene three times and each time 2200 Kg of solvent is used. Determine the concentration of pyridine in the final raffinate .Equilibrium tie-line data for the system water-chlorobenzene-pyridine at 25 °C are given below

Pyridine	Chlorobenzene	Water	Pyridine	Chlorobenzene	water
0	99.95	0.05	0	0.08	99.92
11.05	88.28	0.67	5.02	0.16	94.82
18.95	79.90	1.15	11.05	0.24	88.71
24.10	74.28	1.62	18.90	0.38	80.72
28.60	69.15	2.25	25.50	0.58	73.92
31.55	65.58	2.87	36.10	1.85	62.02
35.05	61.00	3.95	44.95	4.18	50.87
40.60	53.00	6.40	53.20	8.90	37.90
49.00	37.8	13.2	49.00	37.80	13.20

Q.20 1000 kg of pyridine –water solution containing 50% pyridine is to be extracted with equal amount of pure chlorobenzene. The raffinate from the first extraction is to be extracted with a weight of solvent equal to raffinate weight and so on (S2=R1, S3=R2). A) What is the exit concentration and percentage recovery of pyridine after three stages? B) If all the solvent is used in single stage what is the percentage recovery and exit concentration. The equilibrium data and tie line data is as given below

Chlorobenzene Layer (C.B.)			Water Layer		
Pyridine	C.B.	Water	Pyridine	C.B.	Water
0.0	99.95	0.05	0	0.08	99.92
11.05	88.28	0.67	5.02	0.16	94.82
18.95	79.90	1.15	11.05	0.24	88.71
24.10	74.28	1.62	18.90	0.38	80.72
28.60	69.15	2.25	25.50	0.58	73.92
31.55	65.58	2.87	36.10	1.85	62.05
35.05	61.00	3.95	44.95	4.18	50.81
40.60	53.00	6.40	53.20	8.50	37.90
49.00	37.8	13.2	49.00	37.8	13.20

Q.21. If 100 Kg of a solution of acetic acid (c) and water (A) containing 30% of acid is to be extracted three times with isopropyl ether (B) at 20 °C using 40 kg of solvent in each stage , determine the quantities and composition of the various streams . How much solvent would be required if the same final raffinate concentration were to be obtained with one stage? Horizontal lines i.e. the equilibrium data is

Water Layer	**Isopropyl Ether Layer**

Acetic Acid	Water	Iso. Ether	Acetic Acid	Water	Iso. Ether
0.69	98.1	1.2	0.18	0.5	99.3
1.41	97.1	1.5	0.37	0.7	98.9
2.89	95.5	1.6	0.39	0.8	98.4
6.42	91.7	1.9	1.93	1.0	97.1
13.30	84.4	2.3	4.82	1.9	93.3
25.50	71.1	3.4	11.40	3.9	84.7
36.70	58.9	4.4	21.60	6.9	71.5
44.30	45.1	10.6	31.1	10.8	58.1
46.40	37.1	16.5	36.20	15.1	48.7

Q.22 A solution of nicotine in water containing 1 % nicotine is to be extracted with kerosene at 293 0 K (20 0 C) Water and Kerosene are essentially insoluble. Assume the equilibrium relationship to be Y = 0.9 X

Where

Y = kg nicotine / Kg kerosene

X = kg nicotine / kg water

1) Determine the percentage extraction of nicotine if 100 kg of a feed solution is extracted with 150 kg of solvent (Kerosene)
2) Repeat for three theoretical extractions using 50 kg solvent each time.

Q .23. A solution containing 5 % acetaldehyde and 95 % toluene is to be extracted with water in five stages cross current extraction unit to extract acetaldehyde. The toluene and water are essentially insoluble .If 25 kg of water each time are used per 100 kg of feed; calculate the amount of acetaldehyde extracted and the final concentration of the exit solution. The equilibrium relationship is given as Y = 2.20 X

Where Y = Kg acetaldehyde / Kg water and X= kg acetaldehyde/ kg toluene.

Q.24. A continuous column is to be designed to separate a binary feed mixture containing 50 mole % n-heptanes with a distillate product containing 98 mole % n-heptanes and bottom product containing 98 mole % n-octanes. The feed is at its boiling point and operation is at 1 atm. using following equilibrium data. Calculate:

i) Minimum reflux ratio

ii) No. of plates at total reflux

iii) If the reflux ratio is greater than the minimum reflux by 50% used, how many plates are required?

X	0.10	0.30	0.50	0.70	0.90	1.0
Y	0.195	0.585	0.690	0.840	0.950	1.0

Q25. **a)** 350 kg per hour of halibut liver is to be extracted in a counter current cascade with ether to recover oil. The ether which has been partially purified contains 2% oil. The fresh liver contains 20% oil and are to be extracted to a composition 10% oil (on solvent free basis)250 kg of solvent is to be used.

i) What % of oil entering with the liver is recovered in the extract?
ii) How many equilibrium stages are required?

Data:

Kg oil/kg solution	0	0.1	0.2	0.3	0.4	0.5	0.6
Kg solution/kg exhausted liver	0.288	0.368	0.44	0.51	0.6	0.71	0.87

Q.26. Roasted copper ore containing copper as $CuS0_4$, is to be extracted in a counter current extractor. The feed charge to be treated per hour comprises of 10 tones of gangue, 1.2 tones of copper sulphate and 0.5 tone of water. The strong solution produced is to consist of 90% H_2O and 10% $CuSO_4$ is to be 98% of that of ore. Pure water is to be used as the fresh solvent. After each stage one tone of water plus copper sulphate dissolved in that water. Equilibrium is attained in each stage. How many stages are required?

Q.27. The equilibrium water absorbed by a silica gel in contact with moist air varies linearly with humidity of air.

$Y = 0.034435X$

Where, X = kg water absorbed / kg of dry gel.

Y= humidity of air, kg moisture/kg dry air.

0.5 kg of silica gel containing 5% (dry basis) absorbed water is placed in a collapsible vessel in which there are 10 m^3 of moist air, the partial pressure of water is 15 mmHg. The total pressure and temperature are kept at 1 atm and 298 K respectively. What is the amount of water picked up from the moist air in the vessel by the silica gel? Also calculate the final partial pressure of the water vapors in the vessel and final total pressure in the vessel.

Q.28. Oil is to be extracted from meal by means of benzene using continuous counter-current extraction unit. The unit is expected to treat 1000 Kg of meal per hour the untreated meal contains 365 Kg of oil and 30 Kg of benzene. The solvent used contains 14 Kg of oil and 590 Kg of benzene. The exhausted solid are to contain 55 Kg of unextracted oil. Experimental data on the extraction of oil from meal are as follows.

Solution composition Kg oil/ Kg solution	0	0.10	0.20	0.30	0.40	0.50	0.60	0.70
Solution retained Kg oil/Kg solid	0.5	0.505	0.515	0.530	0.550	0.571	0.595	0.620

Find the number of ideal stages required?

Q.29. The equilibrium relation for the decolourisation operation is $Y = 0.5 X^{0.5}$ where Y= gm color removed / gm of adsorbent, X = gm color in oil / 1000 gm of color free oil. 100

Kg oil containing one part of color to three part of oil is agitated with 25 Kg of adsorbent. Calculate the percentage color removed, if all 25 Kg of adsorbent is used in one stage.

Q.30. A solution of washed raw cane sugar is colored by the presence of small amounts of impurities. The solution is to be decolorized by treatment with an adsorptive carbon in a contact filtration plant. The original solution has a color concentration of 9.6 measured on an arbitrary scale and it is desired to reduce color of 0.96. Calculate the necessary dosage of the fresh carbon per 2000 kg solution for a single stage process. The data for an equilibrium isotherm is as follows:

Kg carbon/kg solution	0	0.001	0.004	0.008	0.02	0.04
Equilibrium color	9.6	8.6	6.3	4.3	1.7	0.7

Q.31. A Solution contains 500 Kg Na_2Co_3 and water has a concentration of 25% by wt. of salt. It is cooled from 335 K to 285 K in an agitated mild steel vessel. Wt. of the vessel is 750 Kg. 2.0 % water is lost by evaporation crystals of $Na_2CO_3.10\ H_2O$ are formed. Calculate the yield of crystals and the heat to be removed?

Data: Solubility At 285K: 8.9 Kg/ 100 Kg water.
Heat capacity of solution: 3.6 KJ / Kg K.
Heat Capacity of M.S: 0.5 KJ/ Kg K.
Heat of Solution: 78.5 MJ / KMol.
Latent heat of Vaporization: 2395 KJ/ Kg.

Q.32. Calculate the yield of $MgSO_4.7H_2O$ crystals when 1000 Kg saturated solution of MgSO4 at 353 K is cooled to 303 K .assuming 10 % of the water is lost by evaporation during cooling.

Data: Solubility of $MgSO_4$ at 353 K = 64.2 Kg/ 100 Kg water.
Solubility of $MgSO_4$ at 303 K = 40.8 Kg/ 100 Kg water.
Atomic Wt. Mg: 24, S: 32, O: 16, H: 1

Q.33. A saturated solution of $MgSO_4$ at 353 K is cooled to 303K in a crystallizer. During cooling 4 % of water is lost by evaporation. Estimate the quantity of original saturated solution to be fed to crystallizer per 1000 Kg $MgSO_4.7H_2O$ crystals. Data: Solubility of $MgSO_4$ at 353 K= 64.2 Kg / 100 Kg water, Solubility of $MgSO_4$ at 303 K= 40.8 Kg / 100 Kg water, Atomic weight Mg= 24, S=32, H=1, O=16

Q.34. What is distillation? Define differential distillation and derive Rayleigh equation
Q.35. Define Relative volatility and give significance,
Q.36. Write short note on 1) optimum reflux, 2) flash distillation
Q.37. What do you mean by reflux ratio? Derive Fenske equation for number of theoretical Plates at total reflux.
Q.38. What are the drawbacks of Mc -Cabe Thiele method? Derive equation of q-line And give its significance
Q.39. Give detail procedure of finding number of plates by using ponchon savarit method.

Q.40. Explain in brief extractive distillation and azeotropic distillation

Q.41. Define all types of tray efficiencies. Explain steam distillation

Q. 42. List the commercial leaching processes.

Q.43. Derive the following for fractionating column for enriching section

Y_{n+1} = (R/R+1) X_n + (1/R+1) X_d and for stripping section Y_{m+1} =(L/L-W) X_m + (W/L-W) X_w

Q.44. Explain in Brief steam distillation and flash distillation

Q.45. What is Selectivity?

Q.46. Derive an Expression for finding the number of stages under the condition of constant underflow

Q.47. Give detail procedure for finding the number of stages in multistage countercurrent leaching

Q.48. What are the uses of leaching? Give factors affecting the rate of leaching?

Q.49. Give detail material balance and its application to freundlich adsorption isotherm for multistage counter current adsorption

Q.50. Explain in brief 1) Break through curve 2) Adsorption isotherm

Q.51. state equilibrium in ion exchange and explain ion exchange process

Q.52. Give classification of crystallization equipment's. Explain construction and working of Swenson-walker crystallizer

Q.53. Explain reverse osmosis for water purification

Q.54. Give classification of membrane processes

Q.55. What are different membrane modules?

Q.56. Discuss the methods of operation of liquid- solid contacting in leaching.

Q.57. Write principles of ion exchange process

Q.58.What is adsorption hysteresis

Q.59. Give flux equation for a pressure driven process

Q.60. Explain Ultra filtration along with application

Q.61. Explain the selection criteria for solvent for liquid- liquid extraction.

Q.62. Give the classification of liquid-liquid extraction equipments.

Q.63. Derive an equation to calculate height of paced column

Chemical Engineering Department

Mass Transfer-II

List of Practical:

List of Practical (Minimum 10 Experiments to be performed)

Sr. No.	Name of Experiment	CO Mapped
1	Differential Distillation	CO1
2	Sieve plate column	CO2
3	Vapour-Liquid Equillibria	CO1
4	Packed column distillation	CO2
5	Solid-liquid Extraction	CO4
6	Batch crystallization	CO6
7	Ion exchanger	CO5
8	York scheibel column	CO3
9	Liquid-Liquid Extraction(Ternary Diagram)	CO3
10	Soxlet Apparatus	CO4
11	Characterization of Spray Extraction Column	CO3
12	Steam distillation	CO1

Course: 03

Transport Phenomena

(309350)

[Theory]

Course Syllabus

Transport Phenomena (309349)

Unit 1: Momentum Transport **7 Hrs**

Importance of transport phenomena, analogous nature of transfer process, introduction of viscosity and mechanism of momentum transport: Newton's law of viscosity, Newtonian & Non-Newtonian fluids, pressure and temperature dependence of viscosity, theory of viscosity of gases and liquids. Velocity distribution in laminar flow: Shell momentum balances of - a) Flow of falling film b) Flow through the circular tube c) Flow through an annulus d) Flow in a narrow slit e) Adjacent flow of two immiscible fluids

Unit 2: Energy Transport **7 Hrs**

The introduction of thermal conductivity and mechanism of energy transport: Fourier's law of heat conduction, temperature and pressure dependence of thermal conductivity in gases and liquids.

Temperature distribution in solids and in laminar flow & numerical problems -

a) Shell energy balance, boundary conditions b) Heat conduction with electrical heat source c) Heat conduction with a nuclear heat source d) Heat conduction with a viscous heat source e) Heat conduction with a chemical heat source f) Heat conduction with variable thermal conductivity g) Forced and free convection h) Heat conduction in a cooling fin

Unit 3: Mass Transport **7 Hrs**

Introduction of diffusivity and mechanism of mass transport: Definitions of concentrations, velocities and mass fluxes, Fick's law of diffusion, temperature and pressure dependence of mass diffusivity.

Concentration distribution in solids and in laminar flow & numerical problems – a) Shell mass balances, boundary conditions b) Diffusion through stagnant gas film c) Diffusion with heterogeneous chemical reaction d) Diffusion with homogeneous chemical reaction e) Diffusion through Pyrex tube, leaching etc.

Unit 4: Unsteady Momentum Transport **7 Hrs**

Equations of change for isothermal system -

a) The equation of continuity b) The equation of motion c) Equation of change in curvilinear coordinate systems d) Use of equation of change to set up steady flow problem e) Equation of mechanical energy f) Dimensional analysis of equation of change

Unit 5: Interphase transport in isothermal system **7 Hrs**

Interphase transport - a) Defining friction factors b) Friction factors for flow in tube, around spheres & packed column. Macroscopic balances for Isothermal systems - a) The macroscopic mass, momentum and mechanical energy balances b) Sudden enlargement and liquid-liquid ejector c) Semi empirical expressions for Reynolds stresses

Unit 6: Simultaneous & Analogy momentum, heat and mass transfer 7 Hrs

Interphase transport in multi component system - a) Definition of binary mass transfer coefficient in one phase b) Co-relation of binary mass transfer coefficient in one phase at low mass transfer rates c) Co-relation of binary mass transfer coefficient in two phases at low mass transfer rates d) Definition of transfer coefficient for high mass transfer rates Reynolds analogy, Prandtl’s analogy, Chilton and Colburn analogy & Martinnelli’s analogy.

Reference Books:

1. Transport Phenomena, Bird R. B., Stewart and Lightfoot, John Wiley & Sons
2. Analysis heat and mass transfer, Eckert Erg and Brake R. M.
3. Fundamentals of momentum, heat and mass transfer, James Welty, Charles Wick
4. Energy Mass and Momentum transport phenomena in continua”, Slattery J. C.

TE Chemical

309350: Transport Phenomena

Teaching Scheme: Lectures : 3 Hours / Week Tutorial : 2 Hours / Week	**Examination Scheme:** In Semester: 30 End Semester: 70 Term Work: 25 **Total: 125** **Credits: 4**

Course Outcomes (CO's) : Transport Phenomena

After successful completion of this course, students will be able to:

Course Outcomes	Statements	Bloom's Taxonomy	
		Level	Descriptor
C309350.1	Analysis of momentum transport processes by shell momentum balances.	3	Analyse
C309350.2	Analysis of energy transport processes by the shell energy balances	3	Analyse
C309350.3	Analysis and evaluation of mass transport processes by shell mass balances.	3 & 4	Analyse & Evaluation
C309350.4	Formulate the unsteady momentum transport equations of change for isothermal system.	6	Formulate
C309350.5	Formulate the problems along with appropriate boundary conditions for interphase transport in isothermal systems.	6	Formulate
C309350.6	Develop the analogy between momentum, heat and mass transport phenomena.	6	Develop

Mapping of Course Outcomes to Program Outcomes (POs) & Program Specific Outcomes (PSOs):

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) If there is no correlation, put “-“

COs	Program Outcomes												Program Specific Outcomes		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO12	PSO 1	PSO 2	PSO 3
C339350.1	3	3	-	-	-	-	-	-	-	-	-	-	3	3	-
C339350.2	3	3	-	-	-	-	-	-	-	-	-	--	3	3	-
C339350.3	3	3	-	-	-	-	-	--	-	-	-	-	3	3	-
C339350.4	2	3	-	-	-	-	-	-	-	-	-	--	3	3	-
C339350.5	2	2	-	-	-	-	-	-	-	-	-	-	2	2	-
C339350.6	2	2	-	-	-	-	-	-	-	-	-	-	2	2	-
Total	**15**	**16**											**16**	**16**	
Total Wt	**18**	**18**											**18**	**18**	
% Mapping	**83**	**89**											**89**	**89**	
C350	**3**	**3**											**3**	**3**	

Levels: 3 for ≥60 ; 2 for < 60 ≥ 40; 1 for < 40

CO Assessment Tools

Course Outcomes (COs)	Continuous Internal Evaluation				SEE Assessment Tools			
	T1	T2	T3	Assignment	TW	Insem	End sem	
CO309350.1	√			√	√	√		
CO309350.2	√			√	√	√		
CO309350.3		√		√	√		√	
CO309350.4		√		√	√		√	
CO309350.5			√	√	√		√	
CO309350.6			√	√	√		√	

Chemical Engineering Department

Teaching Plan

Transport Phenomena (309350)

Teaching Scheme:	**Examination Scheme:**
Theory: 03 h/week	Insem : 30
	Endsem: 70
Tutorial: 2 h / week	TW : - 25
	Credits : - 4

Lect No.	Topics / Sub- Topics	CO Mapped
1	PO,PSO,CO & Subject orientation	-
2	**Momentum transport** - Importance of transport phenomena, analogous nature of transfer process,	1
3	introduction of viscosity and mechanism of momentum transport: Newton’s law of viscosity, Newtonian & Non-Newtonian fluids,	1
4	Pressure and temperature dependence of viscosity, theory of viscosity of gases and liquids.	1
5	Velocity distribution in laminar flow: Shell momentum balances of - a) Flow of falling film	1
6	b) Flow through the circular tube	1
7	c) Flow through an annulus	1
8	d) Flow in a narrow slit e) Adjacent flow of two immiscible fluids	1
9	Innovative teaching methods- Cross word puzzle, group discussion	1
10	**Energy Transport-**The introduction of thermal conductivity and mechanism of energy transport: Fourier’s law of heat conduction,	2
11	Temperature and pressure dependence of thermal conductivity in gases and liquids.	2
12	Temperature distribution in solids and in laminar flow & numerical problems - a) Shell energy balance, boundary conditions b) Heat conduction with electrical heat source	2
13	c) Heat conduction with a nuclear heat source d) Heat conduction with a viscous heat source	2
14	e) Heat conduction with a chemical heat source f) Heat conduction with variable thermal conductivity	2
15	g) Forced and free convection h) Heat conduction in a cooling fin	2
16	Innovative teaching methods- Flipped class room	2
17	**Mass Transport -** Introduction of diffusivity and mechanism of mass transport: Definitions of concentrations, velocities and mass fluxes	2
18	Fick’s law of diffusion, temperature and pressure dependence of mass diffusivity.	2
19	Concentration distribution in solids and in laminar flow & numerical problems – a) Shell mass balances, boundary conditions	2
20	b) Diffusion through stagnant gas film	2

21	c) Diffusion with heterogeneous chemical reaction	2
22	d) Diffusion with homogeneous chemical reaction	2
23	e) Diffusion through Pyrex tube, leaching etc.	2
24	Innovative teaching methods- Group discussion	2
25	Innovative teaching methods- presentation, group discussion	2
26	**Unsteady Momentum Transport** Equations of change for isothermal system **-** a) The equation of continuity	2
27	b) The equation of motion	2
28	c) Equation of change in curvilinear coordinate systems	2
29	d) Use of equation of change to set up steady flow problem	2
30	e) Equation of mechanical energy	2
31	f) Dimensional analysis of equation of change	2
32	**Interphase transport in isothermal system -**Interphase transport - a) Defining friction factors	2
33	b) Friction factors for flow in tube, around spheres & packed column.	2
34	Macroscopic balances for Isothermal systems - a) The macroscopic mass,	3
35	Macroscopic balances for Isothermal systems - momentum and mechanical energy balances	3
36	b) Sudden enlargement and liquid-liquid ejector	3
37	c) Semi empirical expressions for Reynolds stress	3
38	Innovative teaching methods- Question answer	3
39	Innovative teaching methods- Presentation	3
40	Innovative teaching methods- Solution tricks	3
41	**Simultaneous & Analogy momentum, heat and mass transfer** Interphase transport in multi component system - a) Definition of binary mass transfer coefficient in one phase	4
42	b) Co-relation of binary mass transfer coefficient in one phase at low mass transfer rates	4
43	c) Co-relation of binary mass transfer coefficient in two phases at low mass transfer rates	4
44	d) Definition of transfer coefficient for high mass transfer rates Reynolds analogy,	4
45	Definition of transfer coefficient for high mass transfer rates Prandtl's analogy,	4
46	Definition of transfer coefficient for high mass transfer rates Chilton and Colburn analogy	4
47	Definition of transfer coefficient for high mass transfer rates	
48	Martinnelli's analogy.	
49	Innovative teaching methods- Question answer	

Question Bank

Transport Phenomena (309350)

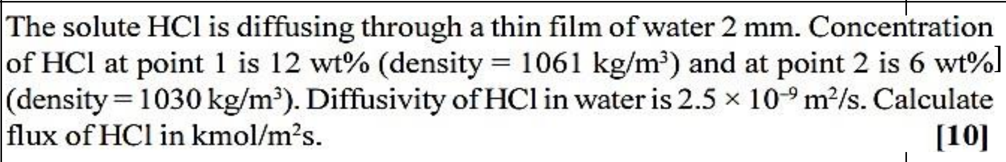
Unit-I

Que.No.1.	Derive the expression of momentum flux and velocity distribution for adjacentflow of two immiscible fluids in a slit which is half-half filled with both fluids.	[CO1]
Que.No.2.	Derive the expression of momentum flux and velocity distribution for laminarflow of a liquid in a narrow slit formed by two vertical parallel walls separatedby distance.	[CO1]
Que.No.3.	Derive expression of volumetric flow rate for power law fluid.	[CO1]
Que.No.4 .	Explain Bingham plastic model.	[CO1]
Que.No.5.	Explain the terms - Lumped parameter system and distributed parameter system. Give example of each.	[CO1]
Que.No.6.	Derive Newton’s Law of viscosity.	[CO1]
Que.No.7.	Explain types of fluids with examples and graph	[CO1]
Que.No.8.	Explain Bingham Model of Non-Newtonian fluid	[CO1]
Que.No.9.	Derive the expression of momentum flux and velocity for Newtonian flow offluid through circular tube.	[CO1]
Que.No.10.	Explain time independent and time dependent fluid	[CO1]
Que.No.11.	Explain time independent and time dependent fluid.	[CO1]
Que.No.12.	Derive the expression of momentum flux, velocity profile, maximum velocity and average velocity for flow in narrow slit.	[CO1]
Que.No.13.	Explain generalized equation of Newton’s law of viscosity.	[CO1]

UNIT-II

Que.No.1.	Derive the expression of temperature distribution for viscous heat source.	[CO2]
Que.No.2.	Derive the expression of heat flux and temperature distribution for electrical heat source.	[CO2]
Que.No.3.	Explain Fourier’s law of heat conduction and boundary conditions to solve heat transfer problems.	[CO2]
Que.No.4.	A copper wire has a radius 2 mm and length 5m. For what voltage drop wouldthe temperature rise at the wire axis be 10°C if the surface temperature of thewire is 20°C.? For copper, Lorenz number is 2.23 × 10-8 volt2 K-2.	[CO2]
Que.No.5.	Explain Procedure to solve heat transfer problem.	[CO2]
Que.No.6.	Derive the expression for heat flux and temperature distribution for nuclear heat source of spherical form.	[CO2]
Que.No.7.	Derive the expression of efficiency of cooling fin.	[CO2]

Unit-III

Que.No.1.	Glycerin is flowing through a horizontal tube 1 ft. long and 0.1 in. inside diameter. For a pressure drop of 40 psi, flow rate is 0.00398 ft3 min–1. Densityof glycerin is 1.261 gm/cc. Find viscosity of glycerin in centipoises.	[CO3]
Que.No.2.	Explain mass balance equation at steady state.	[CO3]
Que.No.3.	Derive Navier Stoke's equation of motion.	[CO3]
Que.No.4.	A viscous fluid is flowing through the horizontal capillary tube. Find radius of capillary from following data : Length of capillary = 50.02 cm Kinematic viscosity of fluid=4.03×10–5 m2/s Density of fluid = 955.2 kg/m3 Pressure drop across capillary tube = 4.829 × 105 N/m2 Mass flow rate through tube = 2.997 × 10–3 kg/s	[CO3]
Que.No.5.	Explain procedure to solve mass transfer problems.	[CO3]
Que.No.6.	Explain Fick's law of diffusion and boundary conditions to solve mass transferproblems.	[CO3]
Que.No.7.	Calculate the mass flux of benzene through a layer of air of 10 mm thicknessat 25^{0}C and 200 KN/M^2 (Total Pressure), partial pressure of benzene is 6000N/m2, the left of layer and 1 KN/m^2 at right side . Masses diffusivity at this temperature and pressure is 4.4 x 10^{-6} m^2/sec.	[CO3]
Que.No.8.	Derive the expression for concentration distribution for diffusion through homogeneous chemical reaction.	[CO3]
Que.No.9.	Explain Following 1. Free and forced convection	[CO3]
Que.No.10.	A Newtonian fluid is confined between two parallel and vertical plates. The surface on the left is stationary and the other is moving vertically at a constantvelocity V$_0$. Assuming that the flow is laminar, solve the velocity profile.	[CO3]
Que.No.11.	 The solute HCl is diffusing through a thin film of water 2 mm. Concentration of HCl at point 1 is 12 wt% (density = 1061 kg/m^3) and at point 2 is 6 wt%] (density = 1030 kg/m^3). Diffusivity of HCl in water is 2.5 × 10^{-9} m^2/s. Calculate flux of HCl in kmol/m^{2}s. **[10]**	
Que.No.12.	Explain Mass Balance Equation.	[CO3]
Que.No.13.	Derive the expression of molar flux, concentration profile and average concentration for homogeneous chemical reaction.	[CO3]
Que.No.14.	State boundary condition used in mass transfer problem	[CO3]

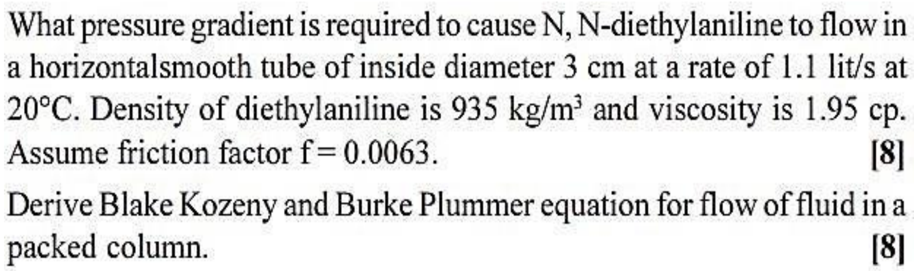
Que.No.15.	Explain pressure and temperature dependence on diffusivity.	[CO3]
Que.No.16.	expression for molar flux and concentration profile for diffusion through stagnant gas film.	[CO3]

Unit-IV

Que.No.1.	Derive continuity equation	[CO4]
Que.No.2.	Explain dimensionless form of equation of change.	[CO4]
Que.No.3.	Derive Euler's equation of motion	[CO4]
Que.No.4.	Explain different types of derivatives used in equation of change.	[CO4]
Que.No.5.	Derive Newton's second law of motion and extend it to derive Euler's equationof motion.	[CO4]
Que.No.6.	Derive equation of change in dimensionless form	[CO4]

Unit-V

Que.No.1.	Derive Ergun equation for flow of fluid through packed bed. Explain itssignificance	[CO5]
Que.No.2.	Explain macroscopic energy balance equation.	[CO5]
Que.No.3.	Derive Ergun equation for flow of fluid through packed bed. Explain its significance.	[CO5]
Que.No.4.	Differentiate between flow in tubes and flow around spheres.	[CO5]
Que.No.5.	What pressure drop is needed for pumping water at 20 °C through a pipe of 25 cm diameter and 1234 m length at a rate of 1.97 m3/s. The pipe is at the same elevation throughout and contains four standard radius 90° elbows and two 45° elbows. The resistance of a standard radius 90° elbows is roughly equivalent to that offered by a pipe whose length is 32 diameters, a 45° elbow,15 diameters. Data: f = 0.0020 for hydro dynamically smooth pipe.	[CO5]
Que.No.6.	Derive expression of velocity distribution for Stormer viscometer in terms of the applied torque.	[CO5]
Que.No.7	Derive Blake-Kozeny and Burke-Plumer equation for flow of fluid through packed bed and extend these equations to derive Ergun equation.	[CO5]
Que.No.8	Show that for laminar flow of fluid through tube, $f \quad \frac{16}{R_e}$	[CO5]
Que.No.9	Derive equation for friction factor for flow in packed column.	[CO5]

Que.No.10	 What pressure gradient is required to cause N, N-diethylaniline to flow in a horizontalsmooth tube of inside diameter 3 cm at a rate of 1.1 lit/s at 20°C. Density of diethylaniline is 935 kg/m^3 and viscosity is 1.95 cp. Assume friction factor f = 0.0063. **[8]** Derive Blake Kozeny and Burke Plummer equation for flow of fluid in a packed column. **[8]**	[CO5]
Que.No.11	Explain friction loss in pipe fitting due to sudden expansion and contraction	[CO5]
Que.No.12	Explain macroscopic momentum balance equation.	[CO5]
Que.No.13	Derive Ergun equation.	[CO5]

Unit-VI

Que.No.1	Derive expression of fanning friction factor and Reynolds number for laminar flow of fluid through tube. [8]	[CO6]
Que.No.2	Explain mass transfer coefficients by film theory.	[CO6]
Que.No.3	Explain Reynold's and Prandtl's analogy.	[CO6]
Que.No.4	Explain Chilton-Colburn analogy.	[CO6]
Que.No.5	Explain Martinnelli's analogy	[CO6]
Que.No.6	Explain correlation of binary transfer coefficient in one phase.	[CO6]
Que.No.7	Explain Reynold's analogy.	[CO6]
Que.No.8	A spherical water droplet 0.05 cm in diameter is falling at velocity of 215 cm/sec through dry. still air at 1 atm pressure. Estimate the instantaneous rateof evaporation from the drop if the drop surface is at 21°C and air at 60°C. The vapor pressure of water at 21°C is 0.0247atm. Assume pseudo steady statecondition and k = 1.35 × 10-3 mol s^{-1} cm^{-2}.	[CO6]
Que.No.9	Write short notes on [16] i. Definition of binary mass transfer coefficient in one phase ii. Definition of transfer coeffecients for high transfer rates.	[CO6]
Que.No.10	Derive the correlation of the binary mass transfer coefficient in one phase at low mass transfer rates.	[CO6]
Que.No.11	Explain transfer coefficient at high transfer rate by film theory	[CO6]

Course: 04

309351 B. Process Instrumentation and Control

(Class: T.E. Chemical)

[Theory]

Chemical Engineering Department

Course Syllabus

309351 B. Process Instrumentation and Control

Unit 1: Fundamentals of Process Instrumentation 7 Hrs

Need and scope of process instrumentation, classification of process variables, measurement problem analysis, basic measurement terms, Functional elements of instruments, static and dynamic characteristics of measuring instruments (zeroth, first, and second-order instruments/ systems), measurement system configuration, transducer elements (types and classification). Intermediate elements: instrument amplifiers, compensators, differential and integrator elements, signal conditioners (signal generation and processing), filtering and signal analysis, data acquisition and conversion (ADC, DAC), digital signal transmission and processing (serial communication, telemetry), indicating and recording elements.

Unit 2: Temperature measuring instruments 7 Hrs

Introduction, classification, temperature scales (units), mechanical temperature sensor (filled system thermometers, expansion thermometers), electrical temperature sensors (RTD, thermistors, thermocouples), radiation sensors (optical and radiation), solid-state sensors, quartz sensors, calibration methods (comparison and fixed point).

Unit 3: Pressure and strain measuring instruments 7 Hrs

Introduction, classification, low, medium, and high pressure measuring instruments, pressure scales (units), manometers, elastic element pressure gauges with pressure equations (using bourdon tube, diaphragms, capsule, and bellows), transduction/ electrical sensors with pressure equations (based on variable capacitance, resistance, and inductance/reluctance-LVDT), force-balance transducers along with mathematical equations, solid-state devices, thin-film transducers, digital transducers, piezoelectric transducers, vibrating element sensors, pressure multiplexer, calibration of pressure sensors using dead- weight tester, Mechanical, optical, and electrical strain gauges.

Unit 4: Level and Flow Measuring Instruments 7 Hrs

Level measuring instruments: Introduction, classification, direct methods (point contact methods, sight or gauge glass methods, buoyancy methods using floats and displacers), indirect methods (hydrostatic pressure methods, capacitance methods, radiation methods, ultrasonic methods, weighing method, sonic methods), solid level measurement. Flow measuring instruments: Introduction, classification (rate of flow and total flow meters), pressure head-type flow meters (orifice plate, venturi tube, flow nozzle, pitot tube), variable- area flow meters (rotameters), electromagnetic, mechanical (positive displacement and turbine- type), anemometer, ultrasonic - type, vortex- flow type, thermal - type, laser anemometers, mass flow meters (cover mathematical treatment for all the sensors).

Unit 5: Instrumental Methods of Chemical Analysis **7 Hrs**

Introduction, classification, basic components of analytical instruments, measurements used Absorption and emission spectrometric methods: ultraviolet (UV), visible, and infrared (IR) spectroscopy, atomic absorption spectroscopy (AAS), mass spectroscopy, Refractometry Chromatographic methods: gas chromatography (GC), liquid chromatography (LC), high performance liquid chromatography (HPLC). Electrochemical methods: measurement of pH, colourimetric, conductometric, potentiometric, Process instruments and automatic on-line analysis

Unit 6: Fundamentals of Process Dynamics **7 Hrs**

Introduction to process dynamics (PD), mathematical tools for process control (laplace transform, complex numbers), ideal forcing functions, control-relevant theoretical process modeling, transfer function and state-space models, poles and zeros of transfer function and their effect on dynamic response, block diagram representation, studying dynamic behavior of linear time invariant (LTI) systems, dynamic behavior of pure gain, pure capacitive, first order, second-order systems, dead time systems (derive differential equation model, transfer function, response to standard test signals and response characteristics along with physical examples), process identification using step response data, Introduction to feedback control system (FBCS), Introduction to ON-OFF, P, PI, PD, PID controllers.

Reference Books:

1. Instrument Engineers’ Handbook (Process Measurement)- Bella G. Liptak, Elsevier
2. Instrument Engineers’ Handbook (Process Control)- Bella G. Liptak, Elsevier
3. Instrumentation devices and systems- Rangan, Sharma, Mani, Tata McGraw Hill Publishing
2. Co. Ltd.
3. Instrumental methods of analysis – Willard, Merritt, Dean, Settle, CBS Publishers and
4. Distributors
5. Instrumental approach to Chemical Analysis- Shrivastava, Jain, S. Chand and Co.
6. Handbook of Analytical Instruments- Khandpur, Tata McGraw Hill Publishing Co. Ltd.
7. Process Control- Bequette, PHI publications
8. Chemical process control- Stephanopoulos, PHI publications
9. Process Dynamics and Control- Seborg, Edgar, Mellichamp- John Wiley and sons Inc.

309351 B. : Process Instrumentation and Control

Teaching Scheme: Lectures : 3 Hours / Week	**Examination Scheme:** In Semester: 30 End Semester: 70 **Total: 100** **Credits: 3**

Course Outcomes (CO's) : Process Instrumentation and Control

After successful completion of this course, students will be able to:

Course Outcomes	**Statements**	**Bloom's Taxonomy**	
		Level	**Descriptor**
C351.1	Understand the basic principles & importance of process control in industrial process plants	**2**	**Understanding**
C351.2	Classify and Categorize with diagram various temperature measuring Instruments	**4**	**Classify**
C351.3	Classify and Categorize with diagram various Pressure measuring Instruments	**4**	**Classify**
C351.4	Classify and Categorize with diagram various Level and Flow measuring Instruments	**4**	**Classify**
C351.5	Understand the use of block diagrams & the mathematical basis for the design of control systems	**2**	**Understanding**
C351.6	Understand the importance and apply of good instrumentation for the efficient design of process control loops for process engineering plants	**2**	**Understanding**

Mapping of Course Outcomes to Program Outcomes (POs) & Program Specific Outcomes (PSOs):

COs	**PROGRAM OUTCOMES**												**PROGRAM SPECIFIC OUTCOMES**		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
C351.1	3	1											2	1	
C351.2	3	2	1										2	2	
C351.3	3	2	1										2	2	
C351.4	3	2	1										2	2	
C351.5	3	2	2	1									2	2	
C351.6	3	2	2	1									2	2	
Total	18	11	7	2									12	11	
Total Wt	18	18	15	6									18	18	
% Mapping	100	61.11	46.7	33.33									66.66	61.11	
C351	3	3	2	1									3	3	

Levels: 3 for ≥60 ; 2 for < 60 ≥ 40; 1 for < 40

CO Assessment Tools

Course Outcomes (COs)	Assessment Tools								
	Continuous Internal Evaluation					Semester End Exam (SEE) conducted by SPPU Pune			
	T1	**T2**	**T3**	**Assignment**	**CIE-Pr**	**OR**	**TW**	**Insem**	**Endsem**
C351.1	√			√				√	
C351.2	√			√				√	
C351.3		√		√					√
C351.4		√		√					√
C351.5			√	√					√
C351.6			√	√					√

Chemical Engineering Department

Teaching Plan

309351 B. Process Instrumentation and Control

Teaching Scheme:
Theory: 03 h/week

Examination Scheme:
Insem: 30
Endsem:70 : Credit = 3

Lect. No.	Topics / Sub- Topics	CO Mapped
1	PO,PSO,CO & Subject orientation	--
2	Classification of process variables	1
3	Characteristics of measuring instruments	1
4	Functional elements of instruments	1
5	Transducer elements	1
6	Intermediate elements	1
7	Filtering and signal analysis,	1
8	Indicating and recording elements	1
9	Classification of temperature sensors	2
10	Mechanical temperature sensors	2
11	Electrical temperature sensors	2
12	Thermocouples	2
13	RTD, thermistors	2
14	Radiation sensors	2
15	Solid-state sensors, quartz sensors	2
16	Calibration methods	2
17	Classification of Pressure measuring instruments	3
18	Manometers	3
19	Elastic element pressure gauges with pressure equations	3
20	Transduction/ electrical sensors with pressure equations	3
21	Force- balance transducers along with mathematical equations	3
22	Thin-film, digital, piezoelectric transducers	3
23	Dead- weight tester, Mechanical strain gauges	3
24	Optical, electrical strain gauges	3
25	Classification of level measuring instruments	4
26	Direct methods	4
27	Indirect methods	4
28	Solid level measurement	4
29	Classification of flow measuring instruments	4
30	Pressure head- type flow meters	4
31	Variable area- type flow meters	4
32	Electromagnetic, Mechanical, Anemometer, Ultrasonic, Thermal, Laser anemometers, Mass flow meters.	4
33	Introduction, classification, components of analytical instruments	5

34	Absorption and emission spectrometric methods ultraviolet (UV), visible, and infrared (IR) spectroscopy	5
35	Atomic absorption spectroscopy (AAS), mass spectroscopy	5
36	Refractometry methods gas chromatography (GC), liquid chromatography (LC)	5
37	High performance liquid chromatography (HPLC).	5
38	Electrochemical methods: measurement of pH, Colourimetric analysis.	5
39	Conductometric, potentiometric analysis.	5
40	Process instruments and automatic on-line analysis	5
41	Introduction to process dynamics	6
42	Mathematical tools for process control	6
43	Dynamic behavior of (LTI) systems	6
44	Dynamic behavior of pure gain, pure capacitive, first order systems	6
45	Dynamic behavior of second-order systems, dead time systems.	6
46	Process identification using step response data	6
47	Feedback control (FBCS), ON-OFF, P, PI controllers	6
48	Feedback control (FBCS) PD,PID controllers	6

Question Bank

309351 B. Process Instrumentation and Control

Unit 1

1. Define Instrumentation and classify the instruments based on function.
2. Explain functional elements of instruments in detail.
3. Explain need and scope of process instrumentation.
4. Explain the difference between accuracy and precision in an instrument.
5. Explain static and dynamic characteristics of a measuring instruments. Give a suitable example.
6. What do you mean by instrumentation? Draw a block diagram of generalized measurement system. Explain it with suitable example.
7. Distinguish between self-operated and power operated instrument.
8. Explain the importance of instrumentation in process industries.
9. Differentiate between Analog and Digital instrument.
10. Define all process variables and state their unit of measurement.

Unit 2

1. Explain the working of the mercury glass thermometer with the help of neat diagram
2. Evaluate the temperature at which Fahrenheit and Centigrade scales coincide
3. Define temperature and give temperature scale with inter relation.
4. Explain with diagram, construction and working of Thermocouple.
5. Explain with diagram, construction and working of Thermister.
6. Explain with diagram, construction and working of Quartz thermometer.
7. Explain RTD with neat diagram.
8. Explain Optical pyrometer with neat diagram.
9. Explain Radiation pyrometer with neat diagram.
10. Write short note on mechanical temperature sensors.
11. Write short note on solid expansion thermometer.
12. Distinguish between RTD and Thermistor.
13. Write short notes on
    a. Thermocouple
    b. RTD
    c. Thermistors
14. Explain Seebeck effect and its application in working of a temperature measuring instruments. Name the instrument with its working diagram.

15. What are transducers? Explain types of transducers.
16. Explain classification of temperature measuring instruments.
17. Explain with diagram, construction, working of filled system thermometers.
18. Distinguish between active and passive transducers with suitable example.
19. A thermometer of time constant 10 seconds, initially at 30 ^{0}C, is suddenly immersed in to a water bath at 100 ^{0}C . how long will it take for the thermometer reading to reach 90 ^{0}C.

Unit 3

1. Enlist various pressure measuring instruments and explain U tube manometer in detail.
2. Enumerate the desirable characteristics of manometric liquids.
3. Explain with diagram, construction and working of Bourdon pressure gauge.
4. Explain LVDT as pressure measuring device.
5 Explain construction, working principle and application of the following:
    a. Bourdon tube
    b. Bellows
    c. Diaphragm
6. Explain with diagram, construction, working and calibration of pressure sensor using dead weight tester.
7. Explain with diagram, construction and working of bellows.
8. Explain with diagram, construction and working of bourdon tube.
9. Explain with diagram, construction and working of diaphragm.
10. Explain construction, working principle and application of McLeod gauge
11. Explain classification of Pressure measuring instruments.
12. Explain with diagram, construction, working of diaphragms.
13. What are different types of manometers? With neat sketch explain inclined leg manometer.
14. What are different types of manometers? With neat sketch explain enlarged leg manometer.
15. What are different types of manometers? With neat sketch explain well manometer.
16. What are transducers? Explain types of transducers.

Unit 4

1. Explain with diagram, construction and working of orifice meter.
2. Explain with diagram, construction and working of venturimeter with its industrial application.
3. Explain with diagram, construction and working of Rota meter with its industrial application.

4. Write short notes on:
    - I. Ultrasonic level method
    - II. Radiation method
    - III. Air purge method
    - IV. Sight glass method
5. Explain classification of flow measuring instruments.
6. Explain classification of level measuring instruments.
7. Explain with diagram, construction and working of ultrasonic level measurement method.
8. Explain with diagram, construction, working and flow equation of orifice meter plate.
9. Explain with diagram, construction, working sight or gauge glass method.
10. How level can be measured using radioactive transducers? Draw neat sketch and explain in detail.
11. Describe turbine type flow meter.
12. Describe following:
    - a. Ultrasonic method of level measurement.
    - b. Turbine type Flow meter
    - c. Electromagnetic flow meter
    - d. Rota meter

Unit 5

1. Write short notes on:
    - I. pH meter
    - II. liquid chromatography
    - III. HPLC
    - IV. Refractometry
2. Explain principle with diagram, construction and working of Gas chromatography
3. Write short notes on mass spectroscopy
4. Describe with neat diagram the following techniques of composition analysis.
    1. IR absorption spectroscopy
    2. Gas chromatography
    3. Ultraviolet Absorption Spectroscopy
    4. Mass spectroscopy
    5. Explain principle with diagram, construction, working of HPLC.

Unit 6

1. State difference between first order and second order system
2. Give classification of process variable with respect to process control.
3. With the help of block diagram explain working of feedback control system.
4. Describe the heat exchanger automatic control system with block diagram.
5. Explain with diagram different control actions
6. Describe the characteristics of step response of second order under damped system.
7. Derive the dynamic response equation of first order system for step change.
8. Explain with equation, different control actions.
9. Describe the types of ideal forcing function.
10. Derive the transfer function of mercury in glass thermometer and find the dynamic behaviour for step change in input.
11. What are servo and regulatory operation?
12. Explain modes of control action.
13. An air to open valve on the inflow controls level in a tank. When the process is at the set point the valve opening is 50%. An increase in outflow results in the valve opening increasing to a new steady state value of 70%. What is the resulting offset if the controller PB is

1. 10%
2. 20%

14. Explain features of controller action

1. Auto/ Manual switch
2. Direct/Reverse action

309352: Internship

Teaching Scheme: Internship : 4 Hours / Week	**Examination Scheme:** **Total: 100** **Credits: 4**

Course Outcomes (CO's) : Internship

After successful completion of this course, students will be able to:

Course Outcomes	**Statements**	**Bloom's Taxonomy**	
		Level	**Descriptor**
C347.1	Learn the basic concepts and apply the theoretical knowledge in practical demonstration.	**1**	Learning
C347.2	Implement Project Planning in their Industrial In-plant Training Project work.	**3**	Appling
C347.3	Be capable of self-education and clearly understand the value of achieving Perfection in the respective industrial work.	**2**	Understanding
C347.4	Study the concept of Facility, Location & Layout & implement in their Industrial In-plant training work.	**2**	Understanding
C347.5	Understand the impact of engineering solutions and industrial safety in a global and social context.	**2**	Understanding
C347.6	Function on Multi-disciplinary teams and familiar with organizational behaviour and management	**3**	Appling

Mapping of Course Outcomes to Program Outcomes (POs) & Program Specific Outcomes (PSOs):

COs	**PROGRAM OUTCOMES**												**PROGRAM SPECIFIC OUTCOMES**		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
C347.1	2	2	1	2	2	2	2	2	2	2	2	2	3	2	2
C347.2	2	2			2	2	2	2	2	2	2	2	2	2	2
C347.3	2				2	2	2	2	2	2	2	2	2		2
C347.4	2	2	2			2	2	2	2	2	2	2	2	2	2
C347.5	2					2	2	2	2	2	2	2	2		2
C347.6	2					2	2	2	2	2	2	2	2		2
Total	12	6	3	2	6	12	12	12	12	12	12	12	13	6	12
Total Wt	18	9	6	3	9	18	18	18	18	18	18	18	18	9	18
% Mapping	66.67	66.67	50	66.67	66.67	66.67	66.67	66.67	66.67	66.667	66.67	66.67	72.22	66.667	66.667
C347	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2

The T&P cell will arrange internship for students in industries/organization after second, fourth and six/seventh semester(s) or as per AICTE/ affiliating University guidelines. Institutions may also device online system for arranging &managing internships. The general procedure for arranging internship is given below:

- **Step 1: Request Letter/ Email from the office of Training & Placement cell** of the college should go to industry to allot various slotsof4-6 weeks during summer vacation as internship periods for the students. Students request letter/profile/ interest areas may be submitted to industries for their willingness for providing the training. (Sample attached)
- **Step 2: Industry will confirm the training slots** and the number of seats allocated for internships via Confirmation Letter/ Email. In case the students arrange the training themselves the confirmation letter will be submitted by the students in the office of Training& Placement through concerned department. Based on the number of slots agreed to by the Industry, TPO will allocate the students to the Industry. In addition, the internship slots may be conveyed through Telephonic or Written Communication (by Fax, Email, etc.) by the TPO or other members of the T&P cell / Faculty members who are particularly looking after the Final/Summer Internship of the students.
- **Step 3: Students on joining Training** at the concerned Industry / Organization, submit the Joining Report/ Letters / Email.
- **Step 4: Students undergo industrial training** at the concerned Industry / Organization. In-between Faculty Member(s) evaluate(s) the performance of students once/twice by visiting the Industry/Organization and Evaluation Report of the students is submitted in department office/TPO with the consent of Industry persons/ Trainers. (Sample Attached)
- **Step 5: Students will submit training report** after completion of internship.
- **Step 6: Training Certificate** to be obtained from industry.
- **Step 7: List of students** who have completed their internship successfully will be issued by Training and Placement Cell.

PROCEDURES / FORMATS FOR ORGANIZING INTERNSHIPS

FORMAT 1. STUDENT INTERNSHIP PROGRAM APPLICATION

Complete and submit to the TPO/ Internship Program Coordinator. Type or write clearly.

1. Student Name:			
2. Campus Address:			Phone:
3. Home Address:			Phone:
3a. Student email address:			
4. Academic Concentration		5. Internship Semester:__________Year.	
6. Overall GPA:			
9. Internship Preferences			
	Location	Core Area	Company/ institution
Preferance-1			
Preferance-2			
Preferance-3			

Faculty mentor Signature:___________________________Date____________.

Signature confirms that the student has attended the internship orientation and has met all paperwork and process requirements to participate in the internship program, and has received approval from his/her Advisor..

Student Signature:____Date___________.

Signature confirms that the student agrees to the terms, conditions, and requirements of the Internship Program

FORMAT 2: REQUEST LETTER FROM INSTITUTE TO INTERNSHIP PROVIDER

To

The General Manager (HR)

....

....

Subject: REQUEST FOR 04/06 WEEKS INDUSTRIAL TRAINING of B.Tech/4

years Degree Programme,

Dear Sir,

Our Students have undergone internship training in your esteemed Organization in the previous years. I acknowledge the help and the support extended to our students during training in previous years.
/ (For first time industry) You must be aware that AICTE has made
internship mandatory for all technical education students.
In view of the above request your good self to allow our following_
____st
udents for practical raining in your esteemed organization. Kindly accord your permission and give at least one-week time for students to join training after confirmation.

S. No.	Name	Roll No.	Year	Discipline

If vacancies exist, kindly do plan for Campus/Off Campus Interview for____batch passing out student sin above branches. CHECK THIS

A line of confirmation will be highly appreciated. With warm regards,

Yours sincerely,

Training & Placement

FORMAT 3: RELIEVING LETTER OF STUDENT

To

....

....

Subject: Relieving letter of student and Industry.

Dear Sir,

Kindly refer your letter/e-mail dated...........On the above cited subject. As permitted by your good self the following students will undergo Industrial Internship in your esteemed organization under your sole guidance & directions:

S .No.	Name of Students	Roll No.	Branch

This training being an essential part of the curriculum, the following guidelines have been prescribed in the curriculum for the training. You are therefore, requested to please issue following guidelines to the concerned manager/Industrial Supervisor.

1. Internship schedule may be prepared and a copy of the same may be sent to us.
2. Each student is required to prepare Internship diary and report.
3. Kindly check the Internship diary of the student daily.
4. Issue instruction regarding working hours during training and maintenance of the attendance record.

You are requested to evaluate the student’s performance on the basis of grading i.e. Excellent, Very Good, Satisfactory and Non Satisfactory on the below mentioned factors. The performance report may please be forwarded to the undersigned on completion of training in sealed envelope.

S. No.	Name of Students	Evaluation Ranking
a	Attendance and general behavior	
b	Relation with workers and supervisors	
c	Initiative and efforts in learning	
d	Knowledge and skills improvement	
e	Contribution to the organization	

Your efforts in this regard will positively enhance knowledge and practical skills of the students, your cooperation will be highly appreciated and we shall feel obliged.

The students will abide by the rules and regulation of the organization and will maintain a proper discipline with keen interest during their Internship. The students will report to you on dated .... along with a copy of this letter.

Yours sincerely,

Training & Placement Officer

FORMAT 4: STUDENT'S DAILY DIARY/ DAILY LOG

DAY-1		DATE		
Time of arrival		Time of Departure		Remarks
Deptt./Division		Name of finished Product		
Name of HOD/ Supervisor With e-mail id				
Main points of the day				

Signature of Industry Supervisor

FORMAT 5: SUPERVISOR EVALUATION OF INTERN

Student Name:____

Date:____

Work Supervisor:______________________________Title:__________

Company/Organization:_______________________________________

Internship Address:

____

____

Dates of Internship:

From______________________________________To_____________

____

Please evaluate your intern by indicating the frequency with which you observed the following behaviors:

Parameters	Needs improvement	Satisfactory	Good	Excellent
Behaviors				
Performs in a dependable manner				
Cooperates with co-workers and supervisors				
Shows interest in work				
Learns quickly				
Shows initiative				
Produces high quality work				
Accepts responsibility				
Accepts criticism				
Demonstrates organizational skills				
Uses technical knowledge and expertise				
Shows good judgment				
Demonstrates creativity/originality				
Analyzes problems effectively				
Is self-reliant				
Communicates well				

Writes effectively				
Has a professional attitude				
Gives a professional appearance				
Is punctual				
Uses time effectively				

Overall performance of student intern (circle one):

(Needs improvement/ Satisfactory/___________________Good/
____Excellent)

Additional comments, if any:

Signature of Industry supervisor_________________________HR Manager
____

FORMAT 6: STUDENT FEEDBACK OF INTERNSHIP (TO BE FILLED BY STUDENTS AFTERINTERNSHIP COMPLETION)

Student Name:____Date:___________

____

Industrial Supervisor:__________________________________Title:___________

____

Supervisor Email:

Internship is:__________________________________Paid Unpaid________

Company/Organization:

____

Internship Address:

____

____ Faculty

Coordinator:_________________________________Department:

Dates of Internship:

____

From____To

____

Please fill out the above in full detail

Give a brief description of your internship work (title and tasks for which you were responsible): Was your internship experience related to your major area of study?

____________Yes, to a large degree____________Yes, to a slight degree________No, not related at all Indicate the degree to which you agree or disagree with the following statements.

This experience has:	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
Given me the opportunity to explore a career field					
Allowed me to apply classroom theory to practice					
Helped me develop my decision-making and problem-solving skills					
Expanded my knowledge about the work world prior to permanent employment					
Helped me develop my written and oral communication skills					
Provided a chance to use leadership skills (influence others, develop ideas with others, stimulate decision-making and action)					
This experience has:	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
Expanded my sensitivity to the ethical implications of the work involved					
Made it possible for me to be more confident in new situations					
Given me a chance to improve my interpersonal skills					
Helped me learn to handle responsibility and use my time wisely					
Helped me discover new aspects of myself that I didn’t know existed before					
Helped me develop new interests and abilities					
Helped me clarify my career goals					
Provided me with contacts which may lead to future employment					
Allowed me to acquire information and/ or use equipment not available at my Institute					

In the Institute internship program, faculty members are expected to be mentors for students. Do you feel that your faculty coordinator served such a function? Why or why not?

How well were you able to accomplish the initial goals, tasks and new skills that were set down in your learning contract?

In what ways were you able to take a new direction or expand beyond your contract?

Why were some goals not accomplished adequately?

In what areas did you most develop and improve?

What has been the most significant accomplishment or

satisfying moment of your internship?

What did you dislike about the internship?

Considering your overall experience, how would you rate this internship? (Circle one).

(Satisfactory/ Good/ Excellent)

Give suggestions as to how your internship experience could have been improved. (Could you have handled added responsibility?

Would you have liked more discussions with your professor concerning your internship?

Was closer supervision needed?

Was more of an orientation required?

FORMAT 7 : PROFORMA FOR EVALUTION OF INTERNSHIP BY INSTITUTEDEPARTMENT OF TRAINING AND PLACEMENT

Ph.____________________Fax____________________Email ______________________

Evaluation (I)

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1. Name of Student______________________________________Mob. No.
2. College Roll No.______________________________________University Roll No.
3. Branch/Semester______________________________________Period of Training
4. Home Address with contact No.
5. Address of Training Site:
6. Address of Training Providing Agency:
7. Name/Designation of Training In-charge
8. Type of Work
9. Date of Evaluation

    a) Attendance: _ (Satisfactory/ Good/ Excellent)
    b) Practical Work: (Satisfactory/ Good/ Excellent
    c) Faculty's Evaluation: _ (Satisfactory/ Good/Excellent)
    d) Evaluation of Industry:__(Satisfactory/ Good/ Excellent)

Overall grade: (Satisfactory/ Good/ Excellent)

Signature of Faculty Mentor Signature of Internship Supervisor

(Industry) With date and stamp

***Photocopy of the attendance record duly attested by the training in-charge should be attached with the evaluation Proforma**

FORMAT 8: INTERNSHIP EVALUATION REPORT

Name & Address of Organization

Sr. No.	Name of Student	Roll No.	Marks to be awarded by			OVER ALL GRADE
			Punctuality Grade (Satisfactory/ Good/ Excellent)	Maintenance of Daily Diary Grade (Satisfactory/ Good/ Excellent)	Skill Test Grade (Satisfactory/ Good/ Excellent)	

FORMAT 9: ATTENDANCE SHEET

Name & Address of Organization

Name of Student	
Roll. No	
Name of Course	
Date of Commencement of Trg.:	
Date of Completion of Training:	

Initials of the student

Month & Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Note:

1. Attendance Sheet should remain affixed in Daily Training Diary. **Do not remove or tear it off.**
2. Student should sign/initial in the attendance column. Do not mark ‘P’
3. Holidays should be marked in **Red Ink** in attendance column. Absent should be marked as **‘A’ in Red Ink.**

Signature of Company internship supervisor with company stamp/ seal

(Name____) Contact No.