Maharashtra State Board of Technical Education, Mumbai

Teaching and Examination Scheme for Post S.S.C. Diploma Courses

Program Name : Diploma in Chemical Engineering

Program Code : CH | **With Effect From Academic Year: 2017 - 18**

Duration of Program : 6 Semesters | **Duration : 16 Weeks**

Semester : Fourth | **Scheme - I**

S. N.	Course Title	Course Abbreviation	Course Code	Teaching Scheme			Credit (L+T+P)	Examination Scheme												Grand Total
								Theory						Practical						
								Exam Duration in Hrs.	ESE		PA		Total		ESE		PA		Total	
				L	T	P			Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	
1	Chemical Engineering Thermodynamics	CET	22406	4	2	-	6	3	70	28	30*	00	100	40	--	--	--	--	--	--	100
2	Chemical Process Instrumentation and Control	CPI	22407	4	2	2	8	3	70	28	30*	00	100	40	25#	10	25	10	50	20	150
3	Industrial Safety and Maintenance	CIS	22408	3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20	150
4	Fluid Flow Operation	FFO	22409	4	-	4	8	3	70	28	30*	00	100	40	50#	20	50	20	100	40	200
5	Technology of Organic Chemicals	TOC	22410	4	-	4	8	3	70	28	30*	00	100	40	50#	20	50	20	100	40	200
			Total	**19**	**4**	**12**	**35**	--	**350**	--	**150**	--	**500**	--	**150**	--	**150**	--	**300**	--	**800**

Student Contact Hours Per Week: **35 Hrs.** Medium of Instruction: **English**

Theory and practical periods of 60 minutes each. Total Marks : **800**

Abbreviations: ESE- End Semester Exam, PA- Progressive Assessment, L - Lectures, T - Tutorial, P - Practical

@ Internal Assessment, # External Assessment, *# On Line Examination , ^ Computer Based Assessment

* Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain LOs required for the attainment of the COs.

~ For the courses having ONLY Practical Examination, the PA marks Practical Part - with 60% weightage and Micro-Project Part with 40% weightage

- **If Candidate not securing minimum marks for passing in the "PA" part of practical of any course of any semester then the candidate shall be declared as "Detained" for that semester.**
- **In-Plant Training during Summer vacation for minimum Six Weeks at the end of Fourth Semester (Second Year).**

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fourth**

Course Title : **Chemical Engineering Thermodynamics**

Course Code : **22406**

1. RATIONALE

Diploma chemical engineer (also called technologists) have to deal with the interrelation of heat and work with respect to Chemical reactions. To perform the chemical process, they have to use different chemical engineering properties. Chemical thermodynamics based on laws of thermodynamics. This helps diploma chemical engineer to relate thermodynamic properties to the thermodynamic systems. This course is designed to provide understanding about the concept of chemical energy which involve in transformation through chemical reaction or evolved/absorbed from chemical system, internal energy, Enthalpy, Entropy those are required to understand the chemical kinetics.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Apply the principles of chemical engineering thermodynamics in Chemical Process Industry.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Use the concept of equilibrium in chemical thermodynamic process.
b. Apply first law of thermodynamics in Chemical process industry.
c. Analyze basic thermodynamic quantity.
d. Use second law of thermodynamics in process industry.
e. Use concept of chemical equilibrium in chemical process.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical				
				Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
L	T	P			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	2	-	6	3	70	28	30*	00	100	40	--	--	--	--	--	--

(*): Under the theory PA, out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *-Practical;* ***C*** *– Credit*
ESE *-End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

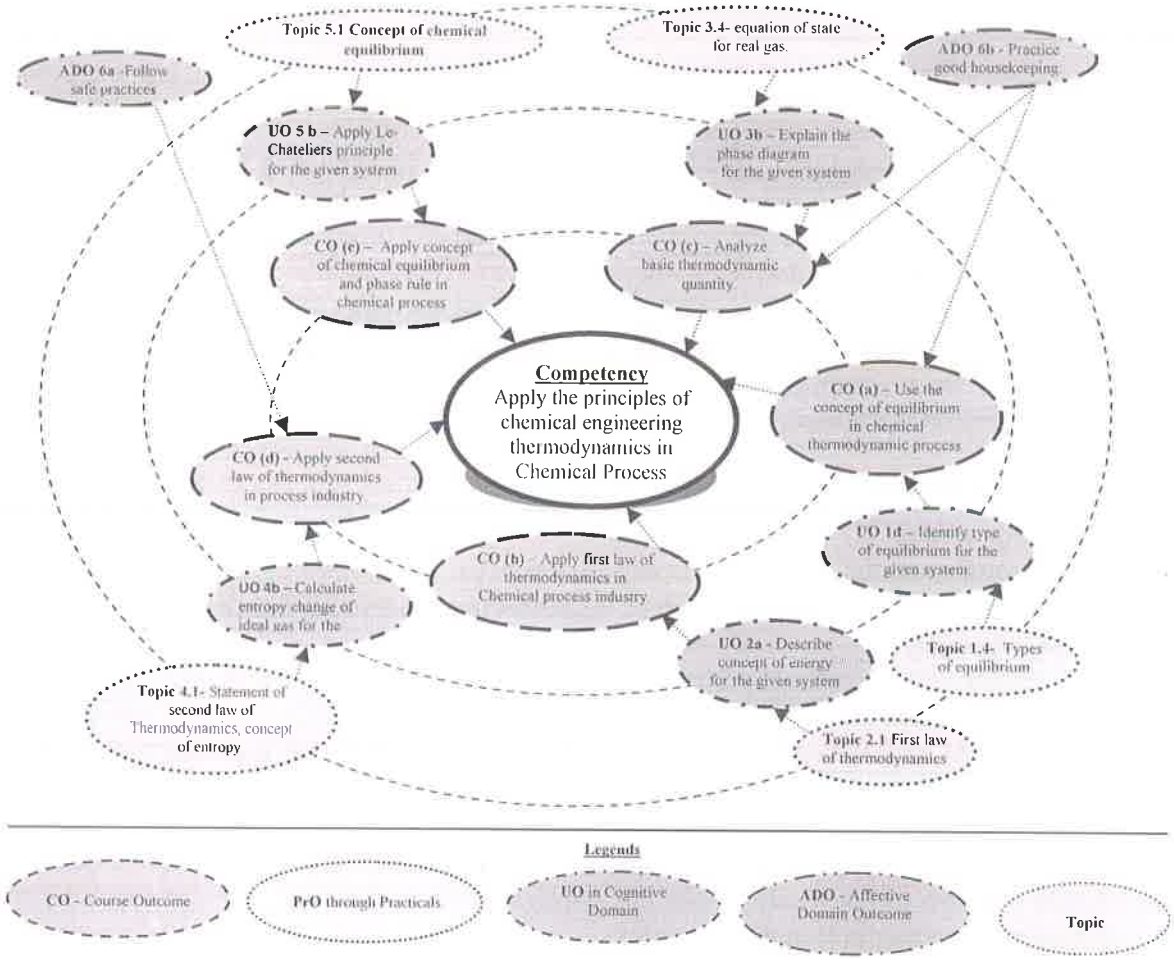

Figure 1 - Course Map

6. SUGGESTED TUTORIALS

The tutorials in this section are sub-components of the COs to be developed and assessed in the student for the attainment of the competency.

S. No.	Tutorial	Unit No.	Approx. Hrs. Required
1	List various thermodynamic properties and thermodynamic processes	I	2
2	Numerical for calculating W,Q,ΔU for heat exchange between system and surroundings	II	2
3	Numerical based on the relation ΔH = U + PV	II	2
4	Numerical for calculating ΔU, Q, W for various processes	II	2
5	Numerical for calculating ΔU, Q, W for various processes	II	2
6	Numerical for finding degree of freedom	III	2
7	Explain the phase diagram for various systems	III	2

S. No.	Tutorial	Unit No.	Approx. Hrs. Required
8	Numerical for calculating pressure(or volume) by ideal gas law and Van der Waals equation	III	2
9	Explain the different thermodynamic diagrams	III	2
10	Numerical based on entropy change of an ideal gas	IV	2
11	Numerical for calculating entropy change during adiabatic mixing, isothermal mixing, chemical reaction	IV	2
12	Numerical to calculate entropy change of a substance at temperature T	IV	2
13	Numerical based on Kp,Kc and Ky.	V	2
14	Numerical to calculate Kp for a reaction from conversion	V	2
15	Numerical to calculate ΔG.	V	2
16	Numerical based on Van't Hoff equation.	V	2
	Total		**32**

Note: The above tutorial sessions are for guideline only. The remaining tutorial hours are for revision and practice

The above tutorials also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Demonstrate working as a leader/a team member.
b. Follow ethical Practices.

The development of the attitude related UOs of Krathwohl's 'Affective Domain Taxonomy', the achievement level may reach:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED:

- Not applicable –

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Thermodynamic Systems and Equlibrium.	1a. Describe the Thermodynamics properties for the given system. 1b. Differentiate extensive and intensive property for the given system. 1c. Identify thermodynamic process for the given	1.1 Scope and limitations of thermodynamics. Basic concepts: System, surrounding, boundary, process, thermodynamic properties, open system, closed system and isolated system, homogenous and heterogeneous system. 1.2 Extensive properties, intensive properties. 1.3 Thermodynamic process: Isothermal

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	system. 1d. Identify type of equilibrium for the given system.	process, Adiabatic process, Isochoric process, Isobaric process, Cyclic process, reversible and irreversible process, quasi static process (definitions) 1.4 Types of equilibrium: stable, unstable, meta stable, thermal, chemical, mechanical, thermodynamic. Thermodynamic function: state function, path function. Macroscopic versus microscopic view.
Unit– II First Law of Thermodynamics	2a. Describe concept of energy for the given system. 2b. Calculate work done for the given system. 2c. Identify heat change for the given system. 2d. Differentiate C_p and C_v for the given system.	2.1 First law of thermodynamics: Law of conservation of Energy, mathematical statement. Concept of different forms of energy, Internal energy, Internal energy as a state function, numerical 2.2 Work and heat as path function. Sign convention used for work and heat, Enthalpy, Heat capacity, specific heat, heat capacity at constant volume, heat capacity at constant pressure. Temperature dependence of heat capacity, relation between Cp and Cv. Numerical for calculating enthalpy. 2.3 Equation of state and concept of ideal gas, processes involving ideal gases: Constant volume process, Constant pressure process, Constant temperature process, Adiabatic process, Polytropic process (Determining ΔU, Q, W for the above processes), numerical 2.4 Throttling process(Joule-Thomson Expansion): Joule-Thomson coefficient, Joule-Thomson porous plug experiment 2.5 Zeroth law of Thermodynamics: statement.
Unit– III Thermodynamic Quantities.	3a. Calculate the degree of freedom for the given system. 3b.Explain the phase diagram for the given system. 3c. Calculate pressure or volume for the given system by Van der Waals equation. 3d. Explain the given thermodynamics diagram.	3.1 Phase, P-V-T behavior of pure fluids: P-V diagram for a pure substance, P-T diagram for a pure substance, T-V diagram for a pure substance 3.2 Degree of freedom, Gibb's phase rule, numerical 3.3 Phase diagram for : Water system , carbon dioxide system and Sulphur system 3.4 Equation of state for real gases: Van der Waals equation, Van der Waals constant. Numerical

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
		3.5 Thermodynamic diagrams: P-H diagram, H-T diagram, T-S diagram, H-S diagram (or Mollier diagram) (stepwise construction not required)
Unit-IV Second Law of Thermodynamics	4a. Apply concept of entropy for the given system. 4b. Calculate entropy change of the ideal gas for the given system. 4c. Apply entropy change for the given system. 4d. Calculate entropy of reaction for the given system.	4.1 Statement of second law of Thermodynamics, concept of entropy. mathematical expression of entropy, standard entropy, relation between first and second law of thermodynamics 4.2 Entropy change of an ideal gas, numerical. 4.3 Clausius inequality: statement and mathematical expression. Calculation of entropy changes during: phase change, adiabatic mixing process, isothermal mixing of ideal gases, chemical reaction, numerical. 4.4 Third law of Thermodynamics: statement, Total entropy change of a substance at temperature T, numerical.
Unit –V Chemical Equilibria	5a. Describe chemical equilibrium for the given system. 5b. Apply Le-Chatelier's principle for the given situation. 5c. Explain the temperature dependency of equilibrium constant for a reaction based on Van't Hoff equation 5d. Derive the relation between thermodynamic equilibrium constant and conversion for the given reaction.	5.1 Concept of chemical equilibrium, relation between K_p, K_c and K_y, numerical. Gibbs free energy change and feasibility of chemical reaction from free energy change. Le-Chatelier's principle. 5.2 Chemical potential, Law of mass action, relation between ΔG and K. Van't Hoff's equation (Derivation), Variation of equilibrium constant with temperature for exothermic and endothermic reaction(based on Van't Hoff's equation), numerical. 5.3 Relation between conversion and thermodynamic equilibrium constant for first order and second order reversible reaction.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER (INTERNAL) DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Thermodynamic system and equilibrium	08	02	02	04	08
II	First law of Thermodynamics	12	04	04	06	14

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
III	Thermodynamic Quantity.	16	02	04	14	20
IV	Second Law of Thermodynamics	14	04	04	06	14
V	Chemical Equlibria	14	04	04	06	14
Total		64	**16**	**18**	**36**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Prepare the presentation based on chemical thermodynamic process.
b. Conduct/ participate in MCQ/Quiz
c. Search the different thermodynamic simulation tools.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the LOs/COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.
f. No. of practical's selection to be performed should cover all units.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a

seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **Visit to plant**: Visit the nearby industry and prepare report about various Thermodynamic operations.
b. **Preparation of model**: Prepare model of reactor showing the thermodynamic operation.
c. **Preparation of chart:** Prepare a chart showing the relationship between first and second law of thermodynamics.
d. **Collection of data**: Collect the data related to thermodynamic for the process industries/Laboratory.
e. **Prepare report:** Prepare a report on difference between enthalpy and internal energy considering example of Hair dryer and filling tank.
f. **Prepare report:** Prepare a report on difference between steady state and equilibrium with example of Hot pot.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	A Textbook of Chemical Engineering Thermodynamics	Narayan, K. V.	PHI Learning PVT Ltd. New Delhi, 2013, ISBN 9788120317321
2	Introduction to Chemical Engineering Thermodynamics	Smith J. M., Van Ness H.C., Abott M.M.	Mc Graw Hill Publication, New York, 1996, ISBN 13:9780073104454,
3	Chemical and Engineering Thermodynamics	Stanley. I. Sandler	Wiley Publication, New Jersey, 1998, ISBN 13:9780471182108
4	Chemical Engineering Thermodynamics	Rao Y. V. C.	Sangam Books, Hyderabad, 1997, ISBN 9780863116889
5	Engineering Thermodynamics	P.K.Nag	Tata Mc-Graw –Hill Publishing Company Ltd,New Delhi ISBN 0-07-059114-8
6	Principles of Physical Chemistry	Puri,Sharma, Pathania	Vishal Publishing Company, Jalandhar. ISBN-13:978-9382956013

14. SOFTWARE/LEARNING WEBSITES

a. www.nptel.ac.in
b. www.msubbu.in
c. http://ocw.mit.edu
d. http://freevideolectures.com


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION MUMBAI

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fourth**

Course Title : **Chemical Process Instrumentation and Control**

Course Code : **22407**

1. RATIONALE

Diploma chemical engineer have to perform monitoring and control of process in the chemical process industry. They have to deal with the instruments related to various process variables like temperature, pressure, level and flow. Diploma chemical engineer also deal with the control actions and implementation of control systems. They have to handle various instruments and control of various chemical engineering processes. This course is developed in the way by which the chemical process control can be performed and related instruments can be handled in safe and efficient manner.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Apply relevant process control parameter in chemical plants.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency.

a. Select the instrument for various chemical processes.
b. Use temperature measuring instruments in chemical industry.
c. Use pressure measuring instruments in chemical industry.
d. Measure the flow and level using various measuring instruments in chemical industry.
e. Select control system for various control action in chemical industry.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
				Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
L	T	P			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	2	2	8	3	70	28	30*	00	100	40	25#	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends:** L-Lecture; T – Tutorial/Teacher Guided Theory Practice; P - Practical; C – Credit, ESE - End Semester Examination; PA - Progressive Assessment.*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

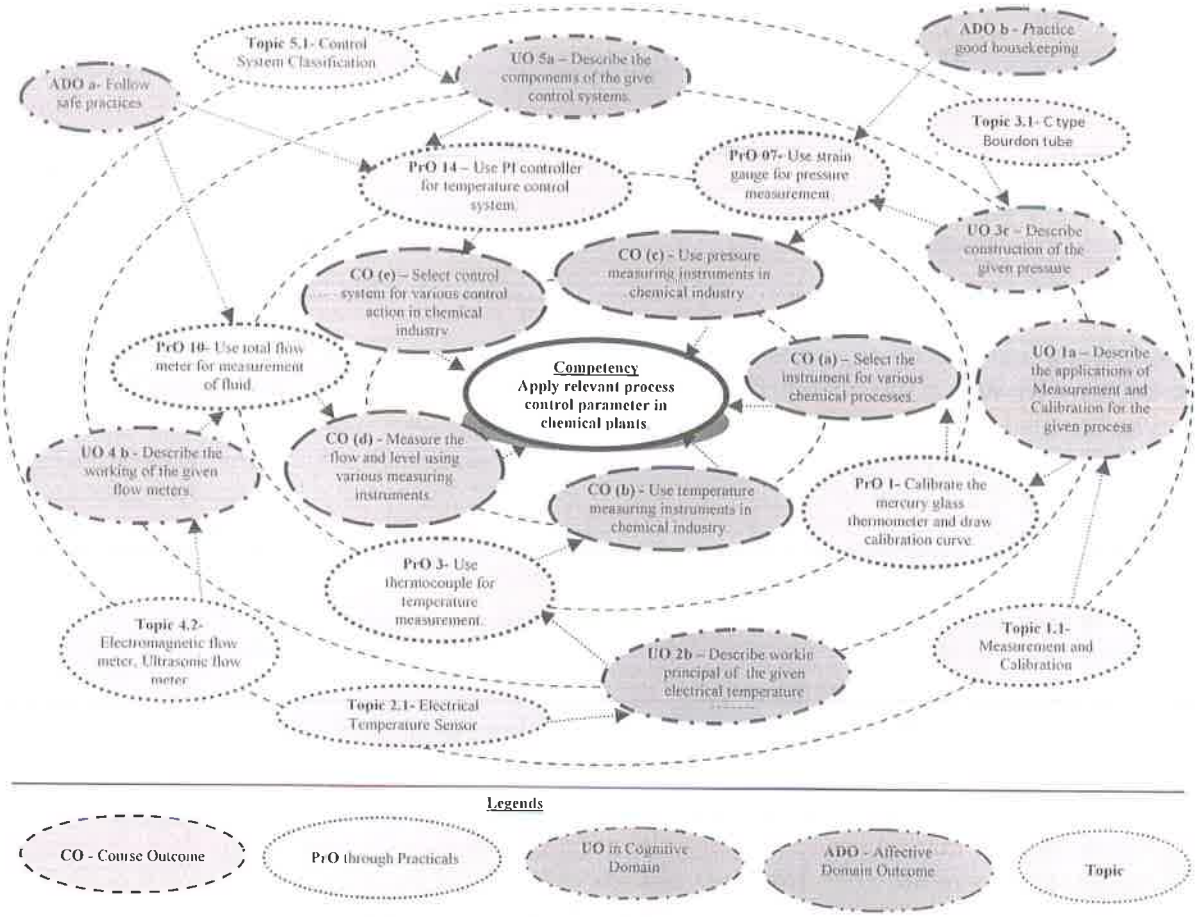

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1.	Calibrate the mercury glass thermometer and draw calibration curve.	I	02
2.	Measure temperature using Resistance temperature detector.	II	02
3.	Use thermocouple for temperature measurement.	II	02
4.	Use pyrometer for high temperature measurement.	II	02
5.	Calibrate pressure gauge by using dead weight tester.	III	02
6.	Measure pressure by using Linear Variable Differential Transducer (LVDT).	III	02
7.	Use strain gauge for pressure measurement.	III	02
8.	Use McLeod gauge for measurement of low pressure.	III	02
9.	Measure the flow of fluid using electromagnetic flow meter.	IV	02
10.	Use turbine flow meter for measurement of fluid.	IV	02
11.	Use air purge method for level measurement of liquid in tank.	IV	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
12.	Use Capacitance probe method for level measurement of liquid in tank.	IV	02
13.	Use ON-OFF controller for temperature control system.	V	02
14.	Use PI controller for temperature control system.	V	02
15.	Use PID controller for temperature control system.	V	02
16.	Determine % flow and % valve opening of control valve and draw characteristics of control valve.	V	02
	Total		**32**

Note

i. *A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S. No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	20
2	Setting and operation	20
3	Safety measures	10
4	Observations and recording	10
5	Interpretation of result and conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safe practices
b. Practice good housekeeping
c. Practice energy conservation
d. Demonstrate working as a leader/a team member
e. Maintain tools and equipment
f. Follow ethical practices

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Mercury in glass thermometer 0 °c to 200°c.	1
2	RTD Standard PT-100 RTD, Digital Voltmeter and ammeter, heater with regulator.	2
3	Thermocouple K type, Cr-Al thermocouple, heater with regulator, Digital temperature indicator.	2
4	Pyrometer (Infrared).	4
5	Dead weight tester, 0 to 40kg/cm^2 predetermined dead weight	5
6	LVDT, Bellows type pressure transducer, inlet pressure 2Kg/cm^2 maximum.	6
7	Strain gauge industrial grade pressure transducer , maximum pressure 10 Kg/cm^2	7
8	Mc Leod gauge	8
9	Electromagnatic flowmeter, size 1", fluid: water, complete assembly	9
10	Rotating vane meter, size 1", fluid: water, complete assembly	10
11	Air purge system, Pipe size 1", fluid: water and air supply	11
12	Capacitance probe with parallel plate assembly	12
13	ON-OFF controller kit, Supply voltage 1.6V to 5.5V max, operating temperature 0 to 100°C,I/O response - high	13
14	PID Controller kit for measuring P, PI, PD, and PID	14,15
15	Pneumatic actuated diaphragm control valve, valve size 1", air to open, seat and plug, SS, complete assembly	16

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Measurement and	1a. Describe the applications of Measurement and Calibration for the given process. 1b. Describe with sketches the direct and indirect method of measurement for the given process. 1c. Describe with sketches the the use of functional elements of the given system. 1d. Explain the causes of dead zone for the given instrument. 1e. Interpret the dynamic characteristic of the given	1.1 Measurement and Calibration: Definition and application 1.2 Measurement methods – Direct and Indirect method 1.3 Functional elements - Primary, secondary, manipulating element , data transferring element 1.4 Static characteristics – definition of Accuracy, Precision, Repeatability, Drift, Sensitivity, Dead zone, causes of dead zone and Static error 1.5 Dynamic characteristics – Speed of Response, Time lag, Dynamic Error

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	instrument.	
Unit-II Temperature Measurement	2a. Explain with sketches the working of the given type of thermometer 2b. Explain with sketches the working principle of the given type of electrical temperature sensors. 2c. Describe with sketches the construction of the given type of pyrometer. 2d. Explain with sketches the working of the given type of pyrometer	2.1 Expansion thermometer : Principle, construction and application, spiral bimetallic thermometer, mercury in glass thermometer 2.2 Electrical Temperature Sensor: principle, construction and application, resistance temperature detector, thermocouple and themister 2.3 Pyrometer: Principle , construction and application, optical and radiation pyrometer
Unit– III Pressure Measurement	3a. Describe with sketches the construction of the given type of pressure gauge. 3b. Explain with sketches the use of dead weight tester for calibration of the given pressure gauges. 3c. Describe with sketches the function of the given type of electrical Pressure Transducer. 3d. Explain with sketches the use of the given type of low pressure measurement.	3.1 C type Bourdon tube, bellows and metallic diaphragm gauge : principle, construction and application 3.2 Force balance pressure gauge – principle, construction and application, dead weight tester 3.3 Electrical Pressure Transducer – principle, construction and application, LVDT and Strain gauge 3.4 Vacuum Measurement – principle, construction and application, McLeod gauge
Unit– IV Flow Viscosity and Level Measurement	4a. Classify flow measurement instruments on the basis of the given characteristics. 4b. Explain with sketches the working of the given flow meters. 4c. Describe with sketches the construction of the given flow measuring devices. 4d. Explain with sketches the use of direct/indirect method for level measurement of the given liquid. 4e. Explain with sketches the	4.1 Variable area flow meter (Piston type): principle, application 4.2 Electromagnetic flow meter, Ultrasonic flow meter turbine flow meter: principle, construction and application, 4.3 Positive displacement flow meter: Principle, Construction and application, Rotating vane meter 4.4 Thermal Mass Flow meter: principle, construction and application, Heat Transfer type 4.5 Direct method for level measurement : principle, construction and application of High Pressure sight glass level indicator 4.6 Indirect method for level measurement :

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	Ultrasonic and Radioactive methods for the given liquid and solid level measurement	principle, construction and application of hydrostatic level measurement (pressure gauge, differential pressure and air purge) 4.7 Ultrasonic, Radioactive and Capacitance probe type level measurement : principle, construction and application,
Unit –V Process Control System and Control Valve	5a. Describe with sketches the function of the components of the given control systems. 5b. Draw the block diagram of the given control system. 5c. Interpret the control action for the given process. 5d. Describe the characteristics of the given valve. 5e. Identify the valve on the basis of the given sizing parameter with justification.	5.1 Control System Classification – open loop and closed loop 5.2 Servo and regulatory process, comparison 5.3 Automatic control system: block diagram 5.4 Control action – ON-OFF, P, PI, PID (only Pneumatic controller) 5.5 Cascade and Ratio controller: Working 5.6 Distributed Control System and Programmable Logic Controller – principle and block diagram 5.7 Types of control valve – air to open, air to close, Valve characteristics –linear, equal%, quick opening, Valve actuators 5.8 Valve sizing – Range ability and turndown, pressure drop across valve, cavitation 5.9 Valve selection – load variations, pressure drop across valve, system non-linearities 5.10 Solenoid valve – Principle, Construction, working and industrial applications

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Concept of Measurement	04	04	02	00	06
II	Temperature Measurement	08	02	04	06	12
III	Pressure Measurement	08	02	04	06	12
IV	Flow and Level Measurement	12	02	06	08	16
V	Process Control System and Control Valve	16	04	06	14	24
Total		**48**	**14**	**22**	**34**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual*

distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Prepare journals based on practical performed in laboratory.
b. Follow the safety precautions.
c. Use various instruments to measure variables.
d. Library / Internet survey of instruments used for various parameters
e. Prepare power point presentation or animation for understanding different control action and systems

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the LOs/COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Use Flash/Animations to explain various instruments for measurement
f. Guide student(s) in undertaking micro-projects

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **Prepare report**: Prepare report on different temperature measuring instruments used by different industries.

b. **Prepare model**: Prepare working model of control valve.
c. **Prepare charts**: Prepare charts displaying pressure measurement instruments with industrial applications.
d. **Prepare List:** Prepare the list of different flow meters with specific use in process industry.
e. **Prepare the report**: Collect information regarding different level measuring instruments used in industry and prepare report of the same.
f. **Visit of chemical process plant**: Visit nearby industry to observe operation of DCS/PLC control system and prepare the report.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Chemical Process Control: An Introduction to Theory and Practice	Stephanopoulos, George.	Pearson Education India; New Delhi, 2015, ISBN-13: 978-9332549463
2	Process System Analysis and Control	Coughanowr, Donald R. ; LeBlanc, Steven E.	McGraw Hill International, New York, 2009, ISBN-13: 978-0073397894
3	Industrial Instrumentation and Control	Singh, S. K.	McGraw Hill, New Delhi, 2010 ISBN-13 : 978-0070678200
4	Fundamental of Industrial Instrumentation	Barua, Alok	Wiley India Pvt. Ltd. New Delhi, 2011, ISBN-13 : 978-8126528820
5	Industrial Control and Instrumentation	Bolton, W.	Longman, New York, 1991 ISBN-13 : 978-0582068025
6	Instrumentation	Kirk, Franklyn W.; Weedon, Thomas A.; Kirk, Phillip	American Technical Pub; Orland Park, 2010, ISBN: 978-0826934307

14. SOFTWARE/LEARNING WEBSITES

a. http://nptel.ac.in/courses/103103037/1
b. https://ocw.mit.edu/courses/chemical-engineering/10-450-process-dynamics-operations-and-control-spring-2006/lecture-notes/
c. http://textofvideo.nptel.iitm.ac.in/103105064/lec1.pdf
d. http://www.engmatl.com/home/finish/21-manufacturing/186-fundamentals-of-industrial-instrumentation-and-process-control
e. http://www.learnerstv.com/Free-Engineering-Video-lectures-ltv689-Page1.htm
f. http://www.freeengineeringbooks.com/chemical-books-download/Process-dynamics-and-control-Lecture-Notes.php
g. http://www.slideshare.net/CHINTTANPUBLICATIONS/process-dynamics-and-control-53793238
h. http://home.iitk.ac.in/~amandg/Babatunde_A._Ogunnaike,_W._Harmon_Ray_Process_Dynamics,_Modeling,_and_Control___1994.pdf

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fourth**

Course Title : **Industrial Safety and Maintenance**

Course Code : **22408**

1. RATIONALE

Diploma chemical engineers have to deal with Plant safety while working in chemical process industries. This course is intended to develop the skills to plan , organize for the safety and prevent accidents and hazards while working in chemical process industry. Information about the management of hazards in various processes and operations may used to control accidents in chemical process plants. Diploma chemical engineers also have to deal with operating different chemical equipments. This course is designed to equip the students with necessary knowledge and skills for using of safe practices, various types of maintenance and their significance.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Apply maintenance and safety measures in chemical industry.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Select the relevant safety plan and procedure for industry.
b. Use the different hazard assessment technique in Chemical industry.
c. Prepare accident investigation reports in Chemical Industry.
d. Use hazard control methods for industrial hazards.
e. Use the relevant maintenance procedure in Chemical process plant.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory						Practical						
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: L-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment.

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

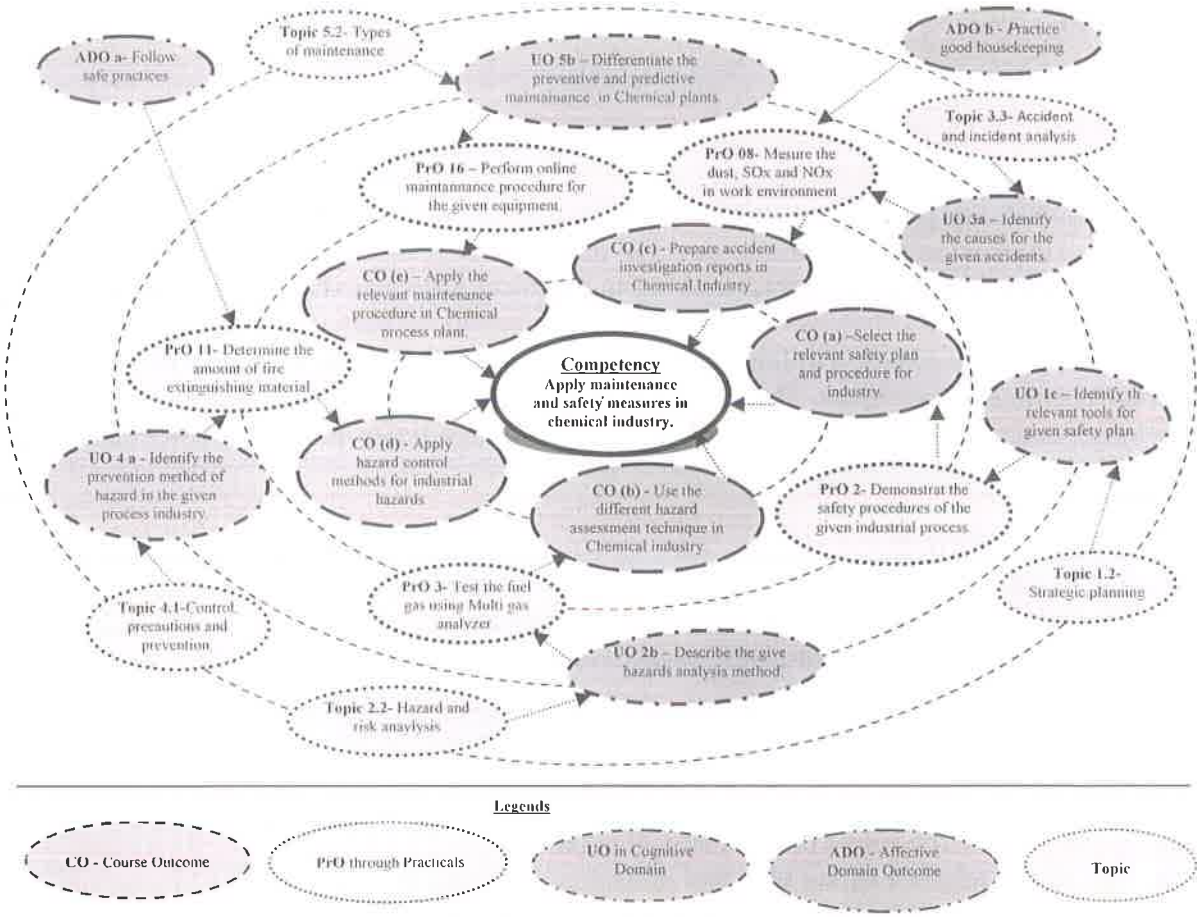

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Use the personal protective equipment for the given industrial hazard protection plan.	I	02*
2	Perform the safety procedures of the given industrial process.	I	02
3	Use the Multi gas analyzer to test the fuel gas using.	II	02*
4	Use the Hygro meter kata thermometer and global thermometer to measure DBT, WBT, relative humidity .	II	02
5	Use the static charge meter to measure the static charge.	II	02
6	Perform the safety audit in the given chemical engineering laboratory.	II	02
7	Use the colorimetric method to mesure the SOx, NOx, NH_3 and Cl_2 gases in work environment.	III	02*
8	Use the high volume semplar to mesure the dust, SOx and NOx in work environment.	III	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
9	Use the Dragger explosive meter to measure the Oxygen level.	III	02
10	Use the audiometer to test the ear.	III	02
11	Use the step test to test the lung function.	III	02*
12	Use the Lux meter to.measure the illumination level	III	02*
13	Use the classical fire extinguisher in laboratory conditions.	IV	02
14	Determine the amount of fire extinguishing material for given type of fire.	IV	02*
15	Perform the mock drill for evacuation in emergency conditions.	IV	02
16	Perform online maintannance procedure for the given equipment of chemical industry.	V	02*
	Total		**32**

Note

i. *A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S. No.	Performance Indicators	Weightage in %
2	Preparation of experimental set up	20
3	Setting and operation	20
4	Safety measures	10
5	Observations and Recording	10
6	Interpretation of result and Conclusion	20
7	Answer to sample questions	10
8	Submission of report in time	10
	Total	**100**

Additionally, the following affective domain LOs (social skills/attitudes), are also important constituents of the competency which can be best developed through the above mentioned laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year and

- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

S. No.	Equipment Name with Broad Specifications	PrO. S. No.
1.	Multi gas analyzer; Multi-component gas analyzer with up to five components featuring NDIR/UV/VIS photometer, paramagnetic and electrochemical O2 , and thermal conductivity sensors.	3
2.	Hygro meter; Measurement ranges 0 to 100% r.h. -30 to 100°C Resolution 0.01% r.h. 0.01°C Accuracy ±2.0% r.h. at 25°C ±0.5°C at 25°C Display dual LCD with 4.5 positions	4
3.	Kata thermometer; alcohol thermometer with a large bulb A 4 cm. long and 2 cm. In diameter and a stern 20 cm. long.	4
4.	Static charge meter; Measurement Range : /- 10kV At 1 Inch, Measurement Accuracy : /- 10%, Indication : 2 ½ Digit LCD Display	5
5.	Colori meter; I/O 4 lines 3.3V general purpose I/O Trigger input 3.3V compliant , Absolute maximum rating 5.8V.	7
6.	High Volume Sempler; sampling flow rate of 20 to 60 standard cubic feet per minute (SCFM), or 0.57 to 1.71 standard cubic meters per minute (SCMM).	8
7.	Dragger explosive meter; Detected Combustible Gases, O2, CO and H2S. Dimensions 1.85 x 5.08 x 1.22 inch (7 x 129 x 31 mm) Weight 7.8 oz (220 g)	9
8.	Audiometer; Frequency range 0 Hz to 22,000 Hz, Frequency stability +/- 0.0001 Hz (at 1000 Hz), S/N 96 dB (in 16 bit systems), Amplitude (SPL) range -20 dB to 100 dB	10
9.	Lux meter; Weight: 150g(without battery), Size: 185*55*30mm Power supply: 2*AAA(7V) battery, Measuring range: 1lux/2000lux/2	12
10.	Fire extinguisher; 5kg CO_2 fire extinguisher.	13

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Safety Planning	1a. Identify the relevant safety plan for the given Industry. 1b. Identify the safety procedures of the given industrial process. 1c. Identify the relevant tools for given safety plan. 1d. Describe the safety policy components for the given industry.	1.1 Safty planning : Defination, purpose, scope and procedure, variety of plans 1.2 Strategic planning: tools of implementation, objective and its role in safety, policy formulation and implementation. 1.3 Organising: Defination, need, nature and principles, organizing for safety.
Unit-II Industrial Hazards	2a. Identify the causes of hazards for the given industrial process. 2b. Describe the given hazards	2.1 Hazards: Types, causes, effects 2.2 Hazard and risk anaylysis: Quantitative and qualitative:

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	analysis method. 2c. Identify the relevant analysis method for the given hazard. 2d. Describe the safety audit procedure for the given industry.	failure, mode and effect analysis(FMEA), maximum credible accident analysis (MCAA), Fault tree analysis, Event tree Analysis 2.3 HAZAN, HAZOP, managerial oversight review technique (MORT), incident technique, critical incident review technique safety integrity levels (SIL). 2.4 Safety Audit: Objective and procedure.
Unit– III Accident and Incident Investigation	3a. Identify the causes for the given accidents. 3b. Describe the process for accident investigation for the given situation. 3c. Prepare the report for the given accident. 3d. Explain the safety audit act for given industrial process.	3.1 Accident and incident investigation : Philosophy, purpose, process and types of investigations, factors and the immediate and basic causes, corrective action, accident investigating agencies. 3.2 Accident reporting : Report forms, writing reports, elements of report. 3.3 Accident and Incident Analysis : Standard classification of factors, methods of data collation and tabulating data, record keeping. 3.4 Factories Act 1948(Ammendment) and Rules: Provisions, rules, amendments, case law under the Factories Act.
Unit– IV Hazards in Chemical Process Plants	4a. Identify the prevention method of hazard in the given process industry. 4b. Describe the safety measures for the given process industry. 4c. Identify the various hazards in the given process industries. 4d. Describe the sampling technique for the given industry.	4.1 Control, precautions and prevention. 4.2 Industrial safety measures: fertiliser, insecticide, pesticides-chlor-alkali, explosives, polymer plants. 4.3 Sampling technique: toxic, flammables, pharmaceuticals, petro-chemical. 4.4 Industrial disaster: Case study, Bhopal, Flixborough industrial disaster.
Unit –V Plant Maintainance	5a. Identify the responsibilities of maintenance department for the given industry. 5b. Differentiate the preventive and predictive maintainance for the given Chemical plant. 5c. Describe the online maintainnance procedure for the given equipment in chemical industry. 5d. Descibe the shutdown and startup procedure for the given chemical plant.	5.1 Plant maintenance: Functions & responsibilities 5.2 Types of maintenance: Corrective or breakdown maintenance, Scheduled maintenance, Preventive maintenance, Predictive maintenance 5.3 Online maintenance (eg. Rotameter/ Steam trap), Shut down maintenance, Procedure for shutdown and start up of plant.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Safety Planning	08	02	04	06	12
II	Industrial Hazards	12	02	08	06	16
III	Accident and Incident Investigation	08	04	04	06	14
IV	Hazards in Chemical Process Plants	12	02	04	08	14
VI	Plant Maintainance	08	02	04	08	14
Total		**48**	**12**	**24**	**34**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Download the videos related to the industrial hazards& rick analysis in process.
b. Prepare the power point presentation on chemical industrial disaster.
c. Collect information related to picktogram& MSDS.
d. Download the maintanance manuals for different chemical process plants.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the LOs/COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Use Flash/Animations to explain various safety aspects of chemical process industries.
f. Guide student(s) in undertaking micro-projects

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually***

undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **Preparation of the safty plan:** Prapare a plan for safety in chemical laboratory in the institute.
b. **Prparation of chart:** Prepare the chart for different industrial hazards.
c. **Preparation of report:** Write a accident investigation report.
d. **Visit chemical process plant:** Visit nearest chemical process plants for identification of hazard and prepare the report.
e. **Preparation of chart:** Prepare the safty awareness chart for the domestic unskilled workers, working in relation with chemical process.
f. **Preparation of Flow chart:** prepare flow chart of the procedure for shutdown and startup of distillation unit in the laboratory.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Industrial Safety Management	Deshmukh, L. M.	McGraw Hill Education; New York, 2005, ISBN-13: 978-0070617681
2	Industrial Safety and Health MAnagement	Asfahl, C. Ray Rieske, David W.	Prentice Hall, N. J. USA, 2009, ISBN-13: 978-007132368711
3	Hazard analysis Techniquies for system safety	Ericson, Clifton A.	Wiley Publication, N.J. USA, 2005, ISBN : 9781118940389
4	Safe and Efficient Plant Operation and Maintenance (Chemical Engineering)	Kraus, Milton N.	McGraw-Hill Inc.,New York US, 1980, ISBN: 978-0070107076
5	Chemical Process Safety	Crowl, Daniel A., Louvar, Joseph F.	Prentice hall, NJ, USA, 2002, ISBN 0-13-018176-5

14. SOFTWARE/LEARNING WEBSITES

a. http://www.rockwellautomation.com/icstriplex/overview.page
b. http://iom.invensys.com/EN/Pages/Triconex.aspx
c. https://www.honeywellprocess.com/en-US/explore/ default.aspx
d. http://www.hima.com/Products/HIMax_default.php
e. http://www.siemens.com/process-safety


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION MUMBAI

Program Name : Diploma in Chemical Engineering

Program Code : CH

Semester : Fourth

Course Title : Fluid Flow Operation

Course Code : 22409

1. RATIONALE

Measurement of pressure, flow and transportation of fluids are part of routine activity in every process industry. Knowledge of fluid flow aspects is also essential for enhancing rate of heat and mass transfer. This course is intended to equip the students with fundamental aspects related to fluid flow. After learning this course students will be able to operate and troubleshoot different fluid transportation devices.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain flow of different fluids in the chemical plants according to the process requirement.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Maintain the fluid parameters in chemical process.
b. Interpret the pressure drop in piping systems.
c. Maintain the flow rate of the incompressible fluid.
d. Select the relevant piping system for fluid transportation.
e. Use liquid pumping devices.
f. Use gas pumping devices.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory						Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	4	8	3	70	28	30*	00	100	40	50#	20	50	20	100	40

(*): Under the theory PA, out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends:* L-Lecture; T – Tutorial/Teacher Guided Theory Practice; P - Practical; C – Credit, ESE - End Semester Examination; PA - Progressive Assessment.**

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

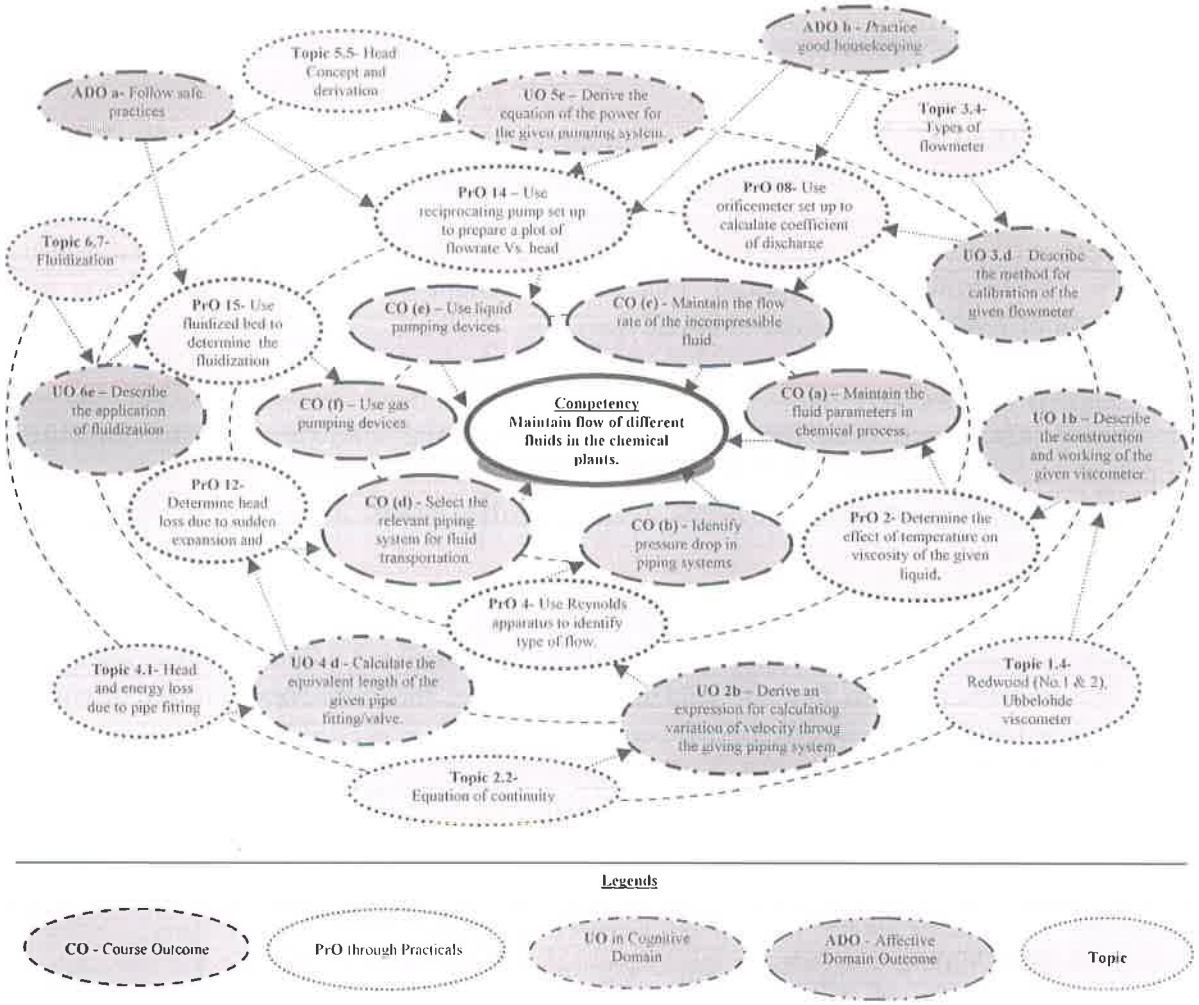

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Use viscometer to measure the viscosity of starch solution of different concentration.	I	04*
2	Determine the effect of temperature on viscosity of the given liquid.	I	04
3	Use U-tube manometer for measuring differential and guage pressure.	I	04
4	Use Reynolds apparatus to identify type of flow.	II	04*
5	Use friction factor set up to determine friction factor and plot friction factor vs Reynold number for a given pipe.	II	04

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
6	Use the experimental set up to calculate viscosity of flowing fluid using Hagen Poisuillie equation.	II	04
7	Use Bernoullie's setup to identify "energy associated with flowing fluid is conserved".	III	04*
8	Use orificemeter set up to calculate coefficient of discharge and prepare calibration curve.	III	04
9	Use the venturimeter set up to calculate coefficient of discharge and prepare calibration curve.	III	04
10	Use the rotameter to measure the flowrate and prepare a curve showing relationship between area and flowrate.	III	04
11	Calculate equivalent length for globe valve, gate valve and bend/elbow.	IV	04*
12	Determine head loss due to sudden expansion and contraction.	IV	04
13	Use the centrifugal pump test rig to plot the characteristics curves.	V	04*
14	Use reciprocating pump set up to prepare a plot of flowrate Vs. head developed.	V	04
15	Use fluidized bed to determine the fluidization velocity for bed of different materials.	VI	04*
16	Use fixed bed of given material, to prepare curve of pressure drop Vs. flowrate.	VI	04
	Total		**64**

Note

i. *A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 24 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S. No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	20
2	Setting and operation	20
3	Safety measures	10
4	Observations and recording	10
5	Interpretation of result and conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safe practices
b. Practice good housekeeping
c. Practice energy conservation
d. Demonstrate working as a leader/a team member

e. Maintain tools and equipment
f. Follow ethical practices

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Viscometer Redwood I &II	1,2
2	U tube manometer	3
3	Reynolds experiment(Transparent tube: Borosilicate Glass/Perspex, capillary tube , needle: copper, stainless steel, constant head water tank : capacity 40 liter, water circulation pump, sump tank : capacity 60 liter, stop watch	4
4	Friction factor set up : set up consists of 2/3 pipes of different diameters, connected in parallel. Pressure tappings to be provided on each pipe with manometer. Water circulation pump, flow measuring tank with piezometer, capacity 25 litre. Sump tank : capacity 50 litre	5
5	Bernoullies setup:Test section – Acrylic(1 piece), piezometer tubes-7, Tank for flow measurement with piezometer, capacity- 25 L, Sump tank capacity-70L, Inlet tank before test section- 20L	7
6	Orificemeter: Orifice plate placed between two flange with an orifice of suitable (orifice dia / pipe dia) ratio. Pressure tappings to be provided at upstream and down stream with manometer.	8
7	Venturimeter: Venturimeter for 1inch pipe line .Convergent cone -15 to 17 ^{0}. Divergent cone – 5 to 7^0. Throat dia- 1.5 to 1.8cm. Pressure tappings to be provided at upstream and throat with manometer.	9
8	Rotameter: 1 inch pipe with 5 to 50 L / minute range	10
9	Equivalent length: An experimental set up consisting of following pipe fittings: Reducer, expander, bend, elbow, gate valve, globe valve. Pump for water circulation, flow measuring tank with piezometer tube, sump tank. . Pressure tappings with manometer to be provided across each fittings	11,12
10	Centrifugal pump: Centrifugal pump coupled to 1 HPmotor,variable speed arrangement, Pressure gauge, vacuum gauge and foot valve, Energy meter or voltmeter and ammeter, flow measuring tank with piezometer tube	13
11	Reciprocating pump: Double acting, Single Cylinder Reciprocating Pump coupled with a DC Motor , RPM Indicator, measuring tank with piezometer tube and stop watch, Vacuum gauge suction line and Pressure gauge on delivery line and a sump tank.	14
12	Fluidized bed:Set up consists of Static bed with packing material , manometer with pressure tappings and rotameter.	15,16

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Fluid Flow Properties	1a. Apply concept of pressure and velocity gradient in the given piping system. 1b. Explain with sketches the construction and working of the given viscometer with sketch. 1c. Classify the fluid on the basis of the given criteria. 1d. Calculate the pressure exerted by the given liquid column.	1.1 Fluid: Definition, pressure gradient, velocity gradient. 1.2 Fluid static and dynamics: concept and applications. 1.3 Viscosity: Origin of viscosity and methods of expression (dynamic viscosity and kinematic viscosity) units and interconversion, neumerical. 1.4 Redwood (No.1 & 2), Ubbelohde viscometer: Principle, construction working and application. 1.5 Newtons law of viscosity. 1.6 Types of fluids : Ideal and real, compressible and incompressible, Newtonian and non Newtonian fluids. 1.7 Hydrostatic equilibrium: Concept and its application in pressure measurement (derivation and elementary problems) Pressure exerted by height of liquid column, differential, guage and absolute pressure measurement by U tube manometer.
Unit-II Fluid Flow Parameters	2a. Calculate velocity and flow rate of the given fluid. 2b. Derive an expression for calculatiog variation of velocity through the giving piping system 2c. Calculate Reynolds number for deciding type of the given flow. 2d. Calculate head loss due to friction from the given data. 2e. Explain with sketches the velocity distribution curve of fluid for the given type of flow.	2.1 Concept of average, point and mass velocity.Volumetric and mass flow rate of fluids , units and interconversion. 2.2 Equation of continuity: Derivation and application. 2.3 Types of flow, demonstration by Reynolds experiment.Concept of lower and upper critical velocity. 2.4 Types of friction, definition of Fanning and Darcy Weisbatch friction factor, derivation of friction factor, relationship between friction factor and Reynold number. 2.5 Velocity distribution across the pipe, relationship between point velocity, average velocity and maximum velocity and its derivation. 2.6 Derivation of Hagen Poiseuille equation and its application.
Unit– III Incompre	3a. Compute the interconversion of energy	3.1 Different types of energy associated with flowing fluids such as pressure energy.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
ssible Fluid Flow Measure ment	at different points in pipe with the given data using Bernoulli's equation. 3b. Explain with sketches the construction and working principle of the given type of flowmeter with sketch. 3c. Derive flow equation for a given flow meter. 3d. Explain with sketches the method for calibration of the given flowmeter. 3e. Calculate the flow rate of the given fluid using variable headmeter.	kinetic energy and potential energy. 3.2 Statement, assumption and derivation of Bernoulli's equation for incompressible fluids and correction. 3.3 Bernoulli's equation: Significance and application, graphical representation of energy variation, flow path for venture test section. 3.4 Types of flowmeter : Variable area and variable head flow meter principle, construction, working and application, calibration of Orifice meter, Venturimeter, Pitot tube and Rotameter.
Unit– IV Pipe Fittings and Valves	4a. Sketch the given pipe fitting/valve. 4b. Identify the relevant pipe fitting for the given application with justification. 4c. Explain the classification of valves using the given criteria. 4d. Calculate the equivalent length of the given pipe fitting/valve.	4.1 Pipe and Tube: definition and comparison. 4.2 Safe working: definition, pressure and allowable stress, Schedule no. and Birmingham wire gauge (BWG). 4.3 Pipe fittings: application, coupling, bend, elbow, tee, cross, reducer, expander, plug, union, hex and barrel nipple. 4.4 Valves: Classification, on/off valve (ball valve/gate valve/plug valve) flow regulating/throttling valve(globe valve/needle valve/ diaphragm valve), unidirectional valve(lift check/swing check valve), safety valve, pressure reducing valve. 4.5 Head and energy loss due to pipe fitting, Concept of equivalent length of pipe fittings and valves numerical. 4.6 Rupture disc: Principle, construction, working and application
Unit –V Liquid Pumping Devices	5a. Explain with sketches the working of the given pump. 5b. Describe with sketches the the construction of the given pump. 5c. Explain with sketches the the characteristics curves for the given pump. 5d. Identify the priming in the given pump with	5.1 Pumping of fluids: Importance of pump. 5.2 Classification of pumps (Centrifugal and positive displacement pump) 5.3 Principle, construction, working and application of centrifugal pump , reciprocating (piston, plunger and diaphragm) pump, rotary pump(gear pump), dosing (piston and peristaltic) pump. 5.4 Power reqirement of centrifugal pump and reciprocating pump (derevation).

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	justification. 5e. Derive the equation of the power for the given pumping system.	5.5 Head: Concept and derivation, Net positive suction head (NPSH), air binding, priming, cavitation. 5.6 Characteristic curves of centrifugal pump, operation and trouble shooting, NPSH, Power required, head developed, numerical.
Unit –VI Gas Pumping Devices	6a. Describe with sketches the construction of the given fan. 6b. Explain with sketches the working principal of the given blower. 6c. Explain with sketches the the construction and application of the given compressor. 6d. Explain with sketches the given vacuum generating device. 6e. Explain with sketches the the application of fluidization for the given system.	6.1 Devices for transportation of gas/air (fan, blower and compressor) 6.2 Induced draft and Forced draft fan: principle, construction and working 6.3 Centrifugal blower: Principle, construction, working and application 6.4 Centrifugal and reciprocating compressor: Principle, construction, working and application 6.5 Fan, blower and compressor: Comparision on the basis of range, 6.6 Vacuum generating devices: Principle , construction,working and application of Steam jet ejector, Oil ring and water ring vacuum pumps 6.7 Fluidization: Concept, minimum fluidization velocity and applications

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Fluid flow properties	8	4	2	4	10
II	Fluid flow parameters	14	2	4	6	12
III	Incompressible fluid flow measurement	14	2	6	8	16
IV	Pipe fittings and valves	8	2	4	2	8
V	Liquid pumping devices	12	2	4	8	14
VI	Gas Pumping devices	8	2	4	4	10
Total		**64**	**14**	**24**	**32**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist students for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Prepare power point presentation about different types of valves.
b. Refer "www.vlab.co.in" and study any one relevant report.
c. Download the sketch of different valves used in a laboratory setup.
d. Download the videos related to measurement of dimension for glass tube in rotameter setup.
e. Visit website of pump manufacturer and download brochure of different types of pumps.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the LOs/COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Use Flash/Animations to explain various theorems in circuit analysis
f. Guide student(s) in undertaking micro-projects

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **Collection of sample:** Collect different samples of pipe fittings and valves from scrapyard.
b. **Prepare cut section:** Prepare cut section of pipe fittings/valves.
c. **Industry visit:** Visit nearby industry and prepare the report on different fitting and valves.

d. **Visit pumping station**: Visit water pumping station of municipal or local body and prepare a report on pumps and piping arrangement.
e. **Fabricate Venturi tube**: Fabricate Venturi tube using plastic pipes/fittings and prepare experimental setup demonstrating its use as pumping device.
f. **Collection of sample:** Collect the sample of different grades of lubricating and machine oil.
g. **Prepare model**: Prepare a model of gear pump/diferent types of impellers using thermocole.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Unit Operations of Chemical Engineering	Mc Cabe, W. L. Smith	Mc Graw Hill Publication, New York, 2004, ISBN -9789339213237
2	Chemical Engineering	Coulson, J. M. and Richardson J.F.	Asian Books Private Ltd, New Delhi, 1980, ISBN: 8186299106
3	Perry's Chemical Engineer's Hand Book	Don W Green, Robert. H. Perry	Mc Graw Hill Publication New York, 2008, ISBN:9780071422949
4	Fluid mechanics and Hydraulic machinery	Bansal, R.K.	Laxmi Publication, New Delhi, 2017, ISBN: 978-8131808153
5	Introduction to Chemical Engineering	Badger, W. L., Banchero, J.T.	Mc Graw Hill Publication, New York, 1955, ISBN: 9780074630501
6	Hydraulics and Fluid Mechanics	Modi, P.N. Seth, S.M.	Standard Book House, New Delhi, 2015, ISBN: 81-900893-74-4

14. SOFTWARE/LEARNING WEBSITES

i. www.vlab.co.in
ii. www.nptel.ac.in
iii. www.pumpsindia.com


MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI

Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fourth**

Course Title : **Technology of Organic Chemicals**

Course Code : **22410**

1. RATIONALE

Diploma chemical engineers have to work as plant operator. During their course of work they have to deal with various aspects of manufacturing technology. It is essential for them to giving maximum output with minimum cost and pollution .This subject will provide information towards raw materials, process and industrial application for manufacturing of organic chemicals like Alcohol, oil, soap, polymer, phenols, pulp and paper these technology will provide necessary skill to perform the job role.

2. COMPETENCY

The aim of this course is to help the students to attain the following industry identified competency through various teaching learning experiences:

- **Apply the concept of organic chemistry in chemical engineering applications.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Use fermentation process for manufacturing of alcoholand its products.
b. Prepare the soap and detergent using relevant oils.
c. Use hiding power principle for manufacturing of paint varnishes and lacquers .
d. Use polymerization process for preparation of various polymers.
e. Prepare phenol using per oxidation process.
f. Prepare pulp and paper using sulphate and suphite process.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	4	8	3	70	28	30*	00	100	40	50#	20	50	20	100	40

(*): Under the theory PA, out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

Legends: L-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the

course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

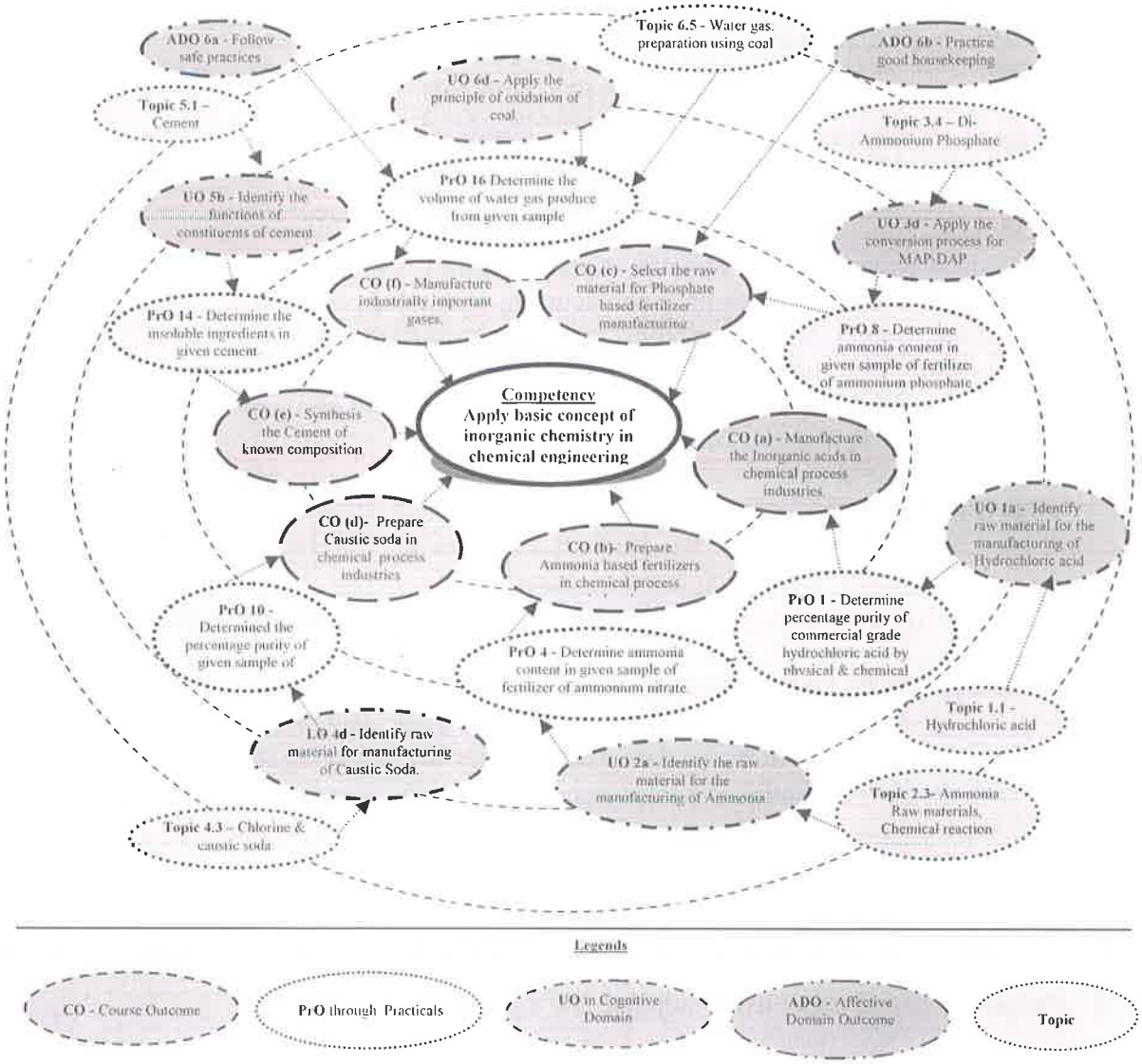

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Estimate the strength of glacial acetic acid by titration.	I	04
2	Prepare ethyl acetate from ethanol and acetic acid.	I	04
3	Determine viscosity of groundnut oil using Redwood viscometer.	II	04
4	Determine viscosity of castor oil using Redwood viscometer.	II	04
5	Determine viscosity of soyabean oil using Redwood viscometer.	II	04
6	Determine iodine value of oil by titration method.	II	04
7	Determine saponification value of lubricating oil by KOH titration method.	II	04

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Estimate the strength of glacial acetic acid by titration.	I	04
8	Determine Acid value of lubricating oil by KOH titration method.	II	04
9	Prepare soap by batch saponification process.	II	04
10	Determined the moisture content of soap.	II	04
11	Determine hiding power of given sample paint.	III	04
12	Determine the percentage of thinner in given sample of oil paint.	III	04
13	Prepare Phenol formaldehyde resin on laboratory scale.	IV	04
14	Determine Acid Value of given sample of polymer.	IV	04
15	Determine Acid Value of given sample of Phenol	V	04
16	Perform Decolourization of paper by bleaching.	VI	04
	Total		**64**

Note

i. *A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 24 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S. No.	Performance Indicators	Weightage in %
2	Preparation of experimental set up	20
3	Setting and operation	20
4	Safety measures	10
5	Observations and Recording	10
6	Interpretation of result and Conclusion	20
7	Answer to sample questions	10
8	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year and
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

S. No.	Equipment Name with Broad Specifications	PrO S. No.
1	Beakers (100ml to 500ml)	All Expt.
2	Burette with stand, 50 ml	All Expt.
3	Thermometer	10,11
4	Redwood Viscometer	03,04,05,
5	Conical flask (100 to250ml.)	All Expt.
6	pipette (10 to 25ml)	All Expt.
7	Measuring cylinder (10 to 50ml)	All.Expt.
8	Weighing balance	All Expt.
9	Ceramic crucible	12,10.09
10	Laboratory oven	10
11	Bottles (250ml)	All Expt.
12	Test Tube (20ml)	All Expt.
13	Iodine flask (250ml)	06

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Alcohol	1a. Identify raw material for manufacturing of the given alcohol. 1b. Describe with sketches the process flow diagram for the given manufacturing of Acetic acid. 1c. Identify the components of chemical reaction for the given manufacturing process with justification. 1d. Describe with sketches the use of esterification process in the given acetate manufacturing.	1.1 Alcohol by molasses: Raw materials, chemical reaction, manufacturing process, Process flow diagram, Industrial applications, , Manufacturing industries. 1.2 Alcohol by corn: Raw materials, chemical reaction, manufacturing process, Process flow diagram, Industrial applications, , Manufacturing industries. 1.3 Acetaldehyde: Raw materials, chemical reaction, manufacturing process, process flow diagram, applications. 1.4 Ethyl acetate and Butanol: Raw materials, chemical reaction, manufacturing process, Process block diagram, industrial applications.
Unit– II Oil, Soap and Detergents	2a. Identify the raw material for manufacturing of the given oil with justification. 2b. Describe with sketches the process flow diagram of manufacturing for the given	2.1 Oil: Raw materials, manufacturing process, process flow diagram Hydrogenation of oil, applications, Economics, manufacturing industries. 2.2 Soap: Raw materials, Chemical reaction, manufacturing process,

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	soap. 2c. Identify the raw material for the given soap with justification. 2d. Identify the components of chemical reaction for the given detergent with justification.	process flow diagram, manufacturing industries 2.3 Detergents - Raw materials, chemical reaction, manufacturing process by sulfated fatty alcohol,
Unit– III Paint, Varnishes and Lacquers	3a. Describe with sketches the applications of the given paint. 3b. Select relevant pigment for the given paint with justification. 3c. Choose use of oil and spirit varnishes with justification. 3d. Describe with sketches the application of the given varnish. 3e. Describe with sketches the application of lacquers in the given industry.	3.1 Paint: Raw materials, manufacturing process, process block diagram, industrial applications, manufacturing industries 3.2 Varnishes: Raw materials, manufacturing process, industrial applications, manufacturing industries 3.3 Lacquers: Raw materials, manufacturing process, industrial applications, and manufacturing industries
Unit-IV Polymers	4a. Describe with sketches the process of addition polymerization for the given polymer. 4b. Describe with sketches the chemical reaction for manufacturing of the given polyester. 4c. Explain the concept of cleavage formation in manufacturing of the given polyester. 4d. Describe with sketches the industrial application of the given polycarbonate.	4.1 Polyethylene: Raw materials, chemical reaction, process flow diagram, manufacturing process, industrial applications, manufacturing industries. 4.2 Polyvinyl chloride: Raw materials, chemical reaction, process flow diagram, manufacturing process, industrial applications, manufacturing industries. 4.3 Polyester: Raw materials, chemical reaction, process flow diagram, manufacturing process, industrial applications, manufacturing industries 4.4 Polycarbonate: Raw materials, chemical reaction, process flow diagram, manufacturing process, industrial applications, manufacturing industries
Unit –V Phenol	5a. Explain the concept of cleavage in the given process. 5b. Explain the concept of alkylation in the given formation. 5c. Describe the process of oxidation in the given preparation of phenol. 5d. Identify ingredients for the given manufacturing process of	5.1 Phenol by Cumene: Raw materials, chemical reaction, process flow diagram, manufacturing process, industrial applications, manufacturing industries 5.2 Phenol by Toluene- Raw materials, chemical reaction, process flow diagram, manufacturing process. 5.3 Phenol by Rasching process- Raw materials, chemical reaction, process

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	Phenol.	flow diagram, manufacturing process.
Unit -VI Pulp and Paper	6a. Identify the raw materials for the given pulp with justification. 6b. Describe with sketches the principle of digester for the given making process of pulp. 6c. Explain with sketches the concept of web formation for the given making process of paper. 6d. Identify the raw material for the given paper with justification.	6.1 Pulp: Raw materials, process flow diagram, manufacturing process (sulphate and sulphite). 6.2 Paper: Raw materials, process flow diagram, manufacturing process, and manufacturing industries

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Alcohol	12	04	06	04	14
II	Oil,Soap and Detergent	12	02	04	04	10
III	Paint,Varnishes and Lacquers	08	00	04	04	08
IV	Polymers	12	04	06	04	14
V	Phenol	12	04	06	04	14
VI	Pulp and Paper	08	02	04	04	10
Total		**64**	**16**	**30**	**24**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist students for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Identify engineering problems based on real world problems and solve with the use of free tutorials available on the internet.
b. Use software's and digital resources for related topics.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.

b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the LOs/COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. **Visit to Distillery plant :** Visit nearby distillery plant and prepare block diagram of process, List of unit operations used, Schematic sketches of each stage of manufacturing processes and process description.
b. **Internet based assignment:** Prepare a power point presentation on a topic " List of organic chemicals manufacturing industries in India"
f. Chemical Engineering aspects in Polymer Industry (Internet based assignment): Identify a Polymer Industry, Make the list of product manufactured, make the list of unit operations and unit processes, Describe the identified unit operations and unit processes, Identify the job role for a chemical engineer in Polymer industry, Safety precautions.
g. Collection of different Polymer sample from market. (Field assignment) : Collect two samples from four companies. Classify the samples on the basis of content. identify the location of industry, Prepare a report based on content and cost
h. Collection of different types of soap and detergent samples Collect two samples from four companies. Classify the samples on the basis of content. identify the location of industry, Prepare a report based on content and cost
i. Visit to Pulp and Paper industry. Visit nearby Pulp and paper plant and prepare block diagram of process, List of unit operations used, Schematic sketches of each stage of manufacturing processes and process description.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Dryden's outline of	Gopal Rao, M. and	East West Publisher, London, 2010.

S. No.	Title of Book	Author	Publication
	Chemical Technology.	Sitting, Marshal	ISBN: 9788185938790,
2	Shreve's Chemical Process Industries.	Austin, George T.	McGraw-Hill Book Company, U.S.A.1984; ISBN: 9780070571471
3	Unit Process of Organic synthesis.	P.H.Groggins	Mc Graw Hill International, New york, 1958 ISBN: 8185938792
4	Reactions and Synthesis	Francis A. Carey, Richard J. Sundberg	Springer, Oxford, 2012, ISBN: 1-4613-9798-7

14. SOFTWARE/LEARNING WEBSITES

a. www. people.clarkson.edu
b. www.creatingtechnology.org
c. www.pafko.com/history
d. www.thechemicalengineer.com/
e. www.iisc.ernet.in
f. www.tep.engr.tu.ac.th
g. www.ichemeblog.org/
h. https://www.acs.org/chemicalsafety
i. www.chemistry.harvard.edu