HEAT TRANSFER OPERATION **Course Code : 315309**

Programme Name/s : Chemical Engineering
Programme Code : CH
Semester : Fifth
Course Title : HEAT TRANSFER OPERATION
Course Code : 315309

I. RATIONALE

This course intends to measure the amount of heat exchanged during the processes and operations. The concept and principles of heat transfer is necessary for the efficient and economical operation of chemical plant. Furthermore, heat transfer equipment also has a significant impact on energy conservation. Optimal selection of heat exchanger equipment enhances the effectiveness of the plant. Using the concepts of conduction, convection and radiation heat losses through pipes and equipment can be estimated.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

Supervise the operation and maintenance of various heat transfer equipment to conserve thermal energy in the chemical industry.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Calculate heat transfer rate by conduction.
- CO2 - Calculate overall heat transfer coefficient using convection.
- CO3 - Use the concept of radiation for heat transfer.
- CO4 - Select appropriate heat exchanger equipment for specific application.
- CO5 - Calculate capacity of evaporator using evaporation process.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme											
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
315309	HEAT TRANSFER OPERATION	HTO	DSC	6	-	4	2	12	4	03	30	70	100	40	25	10	25#	10	25	10	175

Total IKS Hrs for Sem. : 0 Hrs
Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment
Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination
Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 10 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Explain modes of heat transfer. TLO 1.2 State Fourier's law of heat conduction. TLO 1.3 Choose the optimal thickness of insulation material to achieve the lowest total cost. TLO 1.4 Use concept of thermal conductivity to select relevant material for the given application. TLO 1.5 Explain steady and unsteady state heat transfer. TLO 1.6 Derive rate of heat transfer through composite wall, cylinder and sphere.	**Unit - I Heat Transfer by Conduction** 1.1 Introduction to Modes of heat transfer. 1.2 Fourier's law of heat conduction: Mathematical equation, Numericals. 1.3 Concept of conductors and insulators, Characteristics of insulating materials and optimum thickness of insulation. 1.4 Introduction to Thermal conductivity: Mathematical equation, Unit, Equation of relationship between thermal conductivity and temperature, thermal conductivity of materials (metal, non-metal) 1.5 Concept of Steady state and unsteady heat transfer. 1.6 Steady state heat transfer by conduction: Plane wall, Composite wall, Thick wall hollow cylinder, and Hollow sphere, Numericals.	Lecture Using Chalk-Board Presentations Demonstration

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
2	TLO 2.1 Explain types of convection TLO 2.2 Derive heat transfer rate in convection for given application. TLO 2.3 Derive dimensionless analysis to heat transfer by convection TLO 2.4 Calculate heat transfer coefficient using Sider - Tate and Dittus-Bolter equations. TLO 2.5 Draw temperature length diagram for the Co- current and counter-current flow TLO 2.6 Explain types of condensation	**Unit - II Heat Transfer by Convection** 2.1 Convection and its types. 2.2 Individual and overall and heat transfer coefficients: Derivation, Numericals, Concept of fouling factor. 2.3 Dimensional analysis to heat transfer by convection. 2.4 Sieder - Tate and Dittus-Boelter equations for calculating heat transfer coefficients in laminar and turbulent flow, Numericals. 2.5 Flow arrangement in heat exchangers, Log mean temperature difference (LMTD), Numericals. 2.6 Heat transfer in condensation: Types, equation for filmwise condensation on a vertical surface, equation for filmwise condensation on a horizontal tube.	Lecture Using Chalk-Board Presentations Demonstration
3	TLO 3.1 Explain radiation TLO 3.2 Explain absorptivity, reflectivity, transmissivity, Emissivity, Total emissive power, Monochromatic emissive power, monochromatic emissivity, Black body, and Gray body TLO 3.3 State Kirchhoff's law TLO 3.4 Calculate total energy emitted by a black body	**Unit - III Heat Transfer by Radiation** 3.1 Concept of radiation. 3.2 Introduction of absorptivity, reflectivity, transmissivity, Emissivity, Total emissive power, Monochromatic emissive power, monochromatic emissivity, Black body, and Gray body. 3.3 Kirchhoff's laws and its equation. 3.4 Laws of radiation: Stefan-Boltzmann law, Plank's law, Wien's displacement law, Numericals on unlagged steam pipe using Stefan-Boltzmann law.	Lecture Using Chalk-Board Presentations Demonstration
4	TLO 4.1 Explain types of heat exchangers TLO 4.2 Describe with neat sketch double pipe heat exchanger TLO 4.3 Describe with neat sketch of different shell and tube heat exchanger TLO 4.4 Explain with neat sketch of Plate type heat exchanger, and finned tube/extended surface heat exchanger	**Unit - IV Heat Exchanger Equipments** 4.1 Heat transfer equipment and its types, Selection of appropriate heat exchanger equipment. 4.2 Double pipe heat exchanger: Diagram, Construction, Working. 4.3 Shell and tube heat exchanger and its types - Fixed tube sheet, Floating head, U tube, Kettle/ Reboiler,1-2, and 2-4 shell and tube exchangers: Diagram, Construction, Working. 4.4 Plate type heat exchanger, and finned tube/extended surface heat exchanger: Diagram, Construction, working and application.	Lecture Using Chalk-Board Presentations Demonstration

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
5	TLO 5.1 Explain evaporation process. TLO 5.2 Calculate the economy of evaporator to decide the quantity of steam required. TLO 5.3 Describe multiple effect evaporator and vapour recompression to improve economy. TLO 5.4 Explain material and enthalpy balance over single effect evaporator. TLO 5.5 Describe with diagrams of different types of evaporators.	**Unit - V Evaporation Process** 5.1 Introduction to Evaporation, Comparison of evaporation with drying, Effect of properties of solution on evaporation process. 5.2 Performance of evaporator: Capacity and economy. 5.3 Methods to improve economy of evaporators: Multiple effect evaporator (Forward feed, backword feed, and mixed feed) and vapour recompression (Mechanical and thermal). 5.4 Material and enthalpy balance over single effect evaporator. Numericals. 5.5 Open pan (Jacketed pan), Horizontal tube, Short tube vertical/ Calandria type, long tube vertical, forced circulation: Diagram Construction, and working and its application.	Lecture Using Chalk-Board Presentations Demonstration

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Calculate rate of heat transfer by measuring voltage and current. LLO 1.2 Calculate temperature gradient by measuring the temperature of the rod.	1	* Determination of the thermal conductivity of metal rod.	4	CO1
LLO 2.1 Calculate rate of heat transfer by measuring voltage and current. LLO 2.2 Calculate temperature gradient by measuring the temperature of the composite wall.	2	* Determination of the thermal conductivity of composite wall.	4	CO1
LLO 3.1 Calculate rate of heat transfer by measuring voltage and current. LLO 3.2 Measure the surface temperature of the various point as well as ambient temperature. LLO 3.3 Calculate heat loss by using Stefan-Boltzmann law.	3	* Determination of the heat transfer coefficient in natural convection.	4	CO1 CO2
LLO 4.1 Measure the temperature at various point. LLO 4.2 Calculate volumetric flow rate and mass flow rate. LLO 4.3 Calculate heat loss by using Stefan-Boltzmann law.	4	Determination of the heat transfer coefficient in forced convection.	4	CO1 CO2

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 5.1 Measure surface temperature of plate by varying voltage and current. LLO 5.2 Calculate emissivity using Stefan-Boltzmann equation.	5	* Determination of the emissivity of given material	4	CO3
LLO 6.1 Operate the equipment under specific condition. LLO 6.2 Calculate overall heat transfer coefficient based on inner and outer area of the pipe	6	* Determination of the overall heat transfer coefficient in double pipe heat exchanger.	4	CO1 CO2 CO3 CO4
LLO 7.1 Operate the equipment under specific condition. LLO 7.2 Calculate overall heat transfer coefficient based on inner and outer area of the pipe	7	Determination of the overall heat transfer coefficient in finned heat exchanger.	4	CO1 CO2 CO3 CO4
LLO 8.1 Operate the equipment under specific condition. LLO 8.2 Calculate overall heat transfer coefficient based on inner and outer area.	8	Determination of the overall heat transfer coefficient in shell and tube heat exchanger.	4	CO1 CO2 CO3 CO4
LLO 9.1 Prepare 10-20 % NaCl solution LLO 9.2 Calculate capacity of evaporator	9	* Determination of the capacity of open pan evaporator.	4	CO1 CO2 CO3 CO4 CO5
LLO 10.1 Prepare 10-20 % NaCl solution LLO 10.2 Calculate capacity of evaporator LLO 10.3 Calculate steam economy of evaporator	10	Determination of capacity and steam economy of single effect evaporator	4	CO1 CO2 CO3 CO4 CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Micro project

- Fabricate tube sheet: Fabricate tube sheet with triangular pitch arrangement and square pitch arrangement, double pipe heat exchanger.
- Prepare a model: Prepare a model of Double pipe heat exchanger, Shell and tube heat exchanger and its types - Fixed tube sheet, Floating head, U tube, Kettle/ Reboiler,1-2, and 2-4 shell and tube exchangers exchanger, Plate type heat exchanger, and finned tube/extended surface heat exchanger (any one).
- Prepare a model: Prepare a model of open pan evaporator, multiple effect evaporator, horizontal tube, short tube vertical/ Calandria type, and long tube vertical (any one).
- Industrial visit - Prepare a report on heat transfer equipments used in the industry.

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Thermal conductivity metal rod apparatus: Bar = 445 mm, Dia. = 25mm, test length of bar =175 mm, 9 thermocouples on bar and 4 on insulation, Nichrome heater = 400 watt, Cooling jacket = 90 mm dia, Temp. Indicator = 0-200 0C, V-meter = 0-200 V, A-meter = 0-2 Amp	1
2	Thermal conductivity composite wall apparatus: Heater Assembly =1000W, Round coil, Sandwiched, Dia. = 300mm; Test Specimen-Dia. = 300mm, MS = 20mm, Asbestos = 15 mm, Wood =10mm; 8 nos. J type thermocouple, 8 Channel Digital Temperature Indicator; Assembly shall be covered with Wooden Chamber	1
3	Natural Convection apparatus: Dia. of pipe = 0.038m, length of pipe = 0.5 m, duct size = 0.02m*0.02m*0.7m, number of thermocouple = 8	2
4	Forced Convection apparatus: Inside Dia. = 0.026m, Outer diameter = 0.033m, length of pipe = 0.4 m, dia. of orifice = 0.016 m, number of thermocouple = 6	2
5	Emissivity apparatus: aluminium plates, of equal dimensions. Ni-Cr heaters sandwiched in Mica sheets one plate blackbody another natural finish, Dia. = 160 mm, thickness = 12mm, heater = 500W, Digital temp. Indicator	3
6	Double pipe heat exchanger: Inner tube = SS304 -1000mm × 25mm; Outer tube = SS304, 1000mm × 25mm, 25 mm, glass wool with SS304 cover; Hot and cold water tanks = inner SS304, outer MS, 50Litre, Cold water tank, Heater 3 KW; Pumps -2 nos. monoblock 0.5 HP SS304; Rotameter = 1-10 lpm, Glass tube, float SS 316	4
7	Finned tube heat exchanger: Finned tube OD = 20 mm ID =16 mm; 8 fins per inch, OD 45 mm; Water supply = 20 lpm, Temp indicator = 0-200 0C, Water inlet and drain, 0.5 HP blower for air flow, Orifice for 2-inch pipe, Butterfly valve	4
8	Shell and tube heat exchanger: Dia of shell= 0.25 m, Number of baffles = 2, Passes = 1-2, Outer dia. of tube = 0.032 m, Inner dia. of tube = 0.026 m, Nos. of tube = 14/24, Triangular pitch	4
9	Open Pan Evaporator : Pan-Hemispherical SS 304 =500mm dia, 3mm thick, Jacket- MS 525 mm dia, 3mm thick; Lagging- glass wool 40 mm with SS sheet cladding, 12.5 mm steam trap	5

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks

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Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Heat Transfer by Conduction	CO1	12	4	4	6	14
2	II	Heat Transfer by Convection	CO1,CO2	16	2	6	10	18
3	III	Heat Transfer by Radiation	CO1,CO3	6	2	2	4	8
4	IV	Heat Exchanger Equipments	CO1,CO2,CO3,CO4	14	2	4	10	16
5	V	Evaporation Process	CO1,CO2,CO3,CO4,CO5	12	2	6	6	14
Grand Total				**60**	**12**	**22**	**36**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Two Class Test of 30 Marks Each, Term Work Assessment of 25 Marks

Summative Assessment (Assessment of Learning)

- End Term Theory Examination, End Term Practical Examination

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PSO-3
CO1	3	3	1	2	1	2	2			
CO2	3	3	2	2	1	1	2			
CO3	3	1	1	2	2	2	2			
CO4	3	3	1	2	2	3	2			
CO5	3	3	2	2	2	2	2			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	McCabe, Warren L., Julian C. Smith	Unit Operations of Chemical Engineering	McGraw Hill Publication, New York 2004 (Seventh Edition) ISBN-13:9780072848236

Sr.No	Author	Title	Publisher with ISBN Number
2	L. Badger, Julius T. Banchero	Introduction to Chemical Engineering	McGraw Hill Publication, New York 2004 (Seventh Edition) ISBN-10:0073104450
3	Ghosal Salil k.	Introduction to chemical engineering	Tata McGraw Hill Publication, New Delhi, (Reprint 2006) ISBN -10:0074601407
4	Gupta & Prakash	Engineering heat transfer	Nem Chand & Brothers, New Delhi, 1999 (Seventh Edition) ISBN-10:8185240728
5	D. Q. Kern	Process heat transfer	Tata McGraw Hill Publication, New Delhi, (Reprint 2008) ISBN-13: 978-0073104454
6	Domkundwar Arora	Heat and mass transfer operation	Dhanpatrai and co(p) ltd. Dehli ISBN-10: 8177000292
7	S. P. Sukhatme	Heat Transfer	Universities press (India) private limited, Hyderabad ISBN-13: 978-8173715440

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://digimat.in/nptel/courses/video/103101137/L01.html	Introduction to heat transfer
2	https://digimat.in/nptel/courses/video/103101137/L42.html	Condensation
3	http://acl.digimat.in/nptel/courses/video/103103031/L36.html	Evaporation
4	https://digimat.in/nptel/courses/video/103105140/L01.html	Introduction to heat transfer
5	https://www.youtube.com/watch?v=6Zpf3YpkNCM	Heat Transfer
6	http://acl.digimat.in/nptel/courses/video/103105140/L33.html	Internal flow heat transfer
7	https://www.youtube.com/watch?v=KGbw2ZLY9gM	Heat Transfer
8	https://www.digimat.in/nptel/courses/video/103101137/L58.html	Log mean temperature difference
9	https://www.digimat.in/nptel/courses/video/103101137/L57.html	Heat exchanger
10	https://www.youtube.com/watch?v=cLFCtb4uT4o	Conduction
11	https://www.youtube.com/watch?v=qa-PQOjS3zA	Introduction on heat and mass transfer

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students