Chemical Engineering Course Curriculum for B.Tech+Dual Degree w.e.f. 2013 Batch

Oct 2013

Department of Chemical Engineering
Indian Institute of Technology, Bombay

Date Last Updated: 17 Oct 2013

Summary of Credits

BTech Credits:
Total Credits (sem-wise): 35+34+39+32+34+32+35+32= 273
Honors Credits:
273 (BTech credits) +24 (4 electives) = 297
Honors Courses:
Out of the four honors courses, two are core courses and two are electives.
Dual Degree Credits:
297 (Honors credits) + 24 (4 Electives) + 72 (DD Project) = 393

Semester-Wise Schedule

Semester 1

Code	Course	L	T	P	C
MA105	Calculus	3	1	0	8
PH105	Modern Physics	2	1	0	6
CH105+CH107	Organic/Inorganic Chemistry + Physical Chemistry (CH105, CH107 are half sem courses)	4	0	0	8
BB101	Biology (check the structure)	3	0	0	6
CH117	Chemistry Lab	0	0	3	3
PH117	Physics Lab	0	0	3	3
ME113	Workshop Practice	0	0	4	4
					35

Semester 2

Code	Course	L	T	P	C
CS101	Computer Programming & Utilization	2	0	2	6
MA106+MA108	Linear Algebra + Di . Eqns I	3	1	0	8
PH108	Basics of Electricity and Magnetism	2	1	0	6
CL152	Introduction to Chemical Engg.	3	0	0	6
CH117	Chemistry Lab	0	0	3	3
PH117	Physics Lab	0	0	3	3
ME119	Engg. Graphics	0	1	3	5
					34

Semester 3

Code	Course	L	T	P	C
CL203	Intro to Transport Phenomena	2	1	0	6
MA207	Di . Eqns II (MA207 is a half sem course)	3	1	0	4
CL255	Chemical Engineering Thermodynamics I	2	1	0	6
CL244	Introduction to Numerical Analysis	3	1	0	8
HS202	Psych/Sociol/Lit/Phil	3	0	0	6
CL249	Computational Methods Lab	0	0	3	3
					33

Semester 4

Code	Course	L	T	P	C
CL254	Process Fluid Mechanics	2	1	0	6
CL250	Chemical Engineering Thermodynamics II	2	1	0	6
CL246	Heat Transfer	2	1	0	6
CL202	Introduction to Data Analysis (CL2yy is modified version of existing IC102)	3	1	0	8
HS101	Economics	3	0	0	6
CL232	ChE lab 1	0	0	6	6
					38

Semester 5

Code	Course	L	T	P	C
EE101	Intro to Electrical and Electronics Circuits	3	1	0	8
CL324	Chemical Reaction Engineering	3	1	0	8
CL31x	Mass Transfer I	2	1	0	6
CL3xx	Solid Mechanics	2	1	0	6
	(Only course number change for existing solid mechanics: CL231)				
CL333	ChE lab 2	0	0	0	6
					34
	(Honors course 1)				
CL336	Advanced Transport Phenomena	2	1	0	6
					40

Semester 6

Code	Course	L	T	P	C
CL31y	Mass Transfer II	2	1	0	6
CL3xx	Process Control	3	1	0	8
	(Only course number change for existing process control: CL417)				
CL3yy	Chemical Processes	3	0	0	6
	(Only course number change for existing chemical processes: CL408)				
	Inst. elective 1	3	0	0	6
CL335	ChE lab 3	0	0	6	6
					32
	(Honors course 2)				
CL325	Chemical Reaction Engineering II	2	1	0	6
					38

Semester 7

Code	Course	L	T	P	C
	Dept. elective 1	3	0	0	6
	Inst. elective 2	3	0	0	6
CL4xxA+ CL4xxB	Process Equipment Selection + Process Equipment Design	2	2	0	8
	(CL4xxA, CL4xxB are half semester courses each)				
CL4xx	Material Science	3	0	0	6
	(Only course number change for existing material science: CL326)				
CL455	Design Lab	0	0	3	3
	(Only name change for existing CL455: Design Lab I)				
CL433	ChE lab 4	0	0	6	6
					35
	(Honors course 3)				
	Honors elective 1	3	0	0	6
					41

Semester 8

Code	Course	L	T	P	C
	Dept. elective 2	3	0	0	6
	Dept. elective 3	3	0	0	6
CL451	Chemical Process Design	4	0	0	8
	(Increase in credits of existing CL451)				
HS200/ES200	Environmental Studies	3	0	0	6
CL45x	Process Design Project	0	0	6	6
	(Modified version of Design Lab II: CL457)				
					32
	(Honors course 4)				
	Honors elective 2	3	0	0	6
					38

Semester 9 (DD)

Code	Course	L	T	P	C
	DDP I				36
	DD elective 1	3	0	0	6
	DD elective 2	3	0	0	6
					48

Semester 10 (DD)

Code	Course	L	T	P	C
	DDP II				36
	DD elective 3	3	0	0	6
	DD elective 4	3	0	0	6
					48

Course outlines

(Only for new courses or courses whose credits have been modified)

CL255: Chemical Engineering Thermodynamics I [2 1 0 6]

Volumetric Properties of Fluids; First and Second Laws: Steady and Unsteady State Analyses; Availability and Exergy Analysis; Thermodynamic Cycles; Maxwell Relations, Thermodynamic Properties of Real Fluids; Thermodynamics of Ideal Mixtures and Solutions; Concept & Criteria of Chemical Equilibria; Vapour-Liquid Equilibria for Ideal Systems (Raoult's Law); Thermodynamics of Real Mixtures: Use of Partial Molar Properties; Residual and Excess Properties: Fu-gacity and Activity Coe cients; Vapour-Liquid Equilibria for Non-ideal systems; High pressure Vapour-Liquid Equilibria.

Texts/References

1. S. Roy, E-book on Chemical Engineering Thermodynamics, NPTEL Phase II (2012)[Web Link: "http://nptel.iitm.ac.in/courses/103101004/"; last accessed on 8 Feb 2013].
2. S.I. Sandler, Chemical, Biochemical and Engineering Thermodynamics, 4th Edition, Wiley India, 2006.
3. J.M. Smith, H.C. Van Ness and M.M. Abbott, Introduction to Chemical Engineering Thermodynamics, 7th ed., McGraw-Hill, 2005.
4. J.M. Prausnitz, R.N. Lichtenthaler and E.G. Azevedo, Molecular Thermodynamics of Fluid-Phase Equilibria, 3rd ed., Prentice Hall, 1998.

CL249: Computational Methods Lab [0 0 3 3]

(1) Introduction to an Engineering Programming Software (Scilab/Matlab); (2) Error analysis: truncation, roundo , propa-gation; (3) Gaussian elimination and iterative methods for linear algebraic systems; (5) Newton-Raphson: root finding for single and simultaneous equations; (6) Polynomial interpolation, cubic splines; (7) Euler integration; (8) Multistep inte-gration methods; (9) Solving ODEs/PDEs using finite di erence and orthogonal collocation techniques; (10) Regression.

Texts/References

1. Robert J. Schilling, and Sandra L. Harris, Applied Numerical Methods for Engineers: Using Matlab and C, BrooksCole, 2000.
2. S. K. Gupta, Numerical Methods for Engineers, New Age International Publishers (earlier: Wiley Eastern, New Delhi), 2005.
3. Gilbert Strang, Linear Algebra and its Applications, Harcourth Brace Jovanovich, 3rd ed.

CL250: Chemical Engineering Thermodynamics II [2 1 0 6]

Prerequisite: CL25x Chemical Engineering Thermodynamics I

Stability of Thermodynamic Systems; Liquid-Liquid Equilibria; Vapor-Liquid-Liquid Equilibrium; Solid-Liquid Equilibria; Solid-Gas Equilibria; Heat E ects of Chemical Processes / Reaction Equilibria; Thermodynamics of Electrolyte Systems; Thermodynamics of Biosystems; Thermodynamic Analysis of Processes; Introduction to Molecular / Statistical Thermody-namics;

Texts/References

1. S. Roy, E-book on Chemical Engineering Thermodynamics, NPTEL Phase II (2012)[Web Link: “http://nptel.iitm.ac.in/courses/103101004/”; last accessed on 8 Feb 2013].
2. S.I. Sandler, Chemical, Biochemical and Engineering Thermodynamics, 4th Edition, Wiley India, 2006.
3. J.M. Smith, H.C. Van Ness and M.M. Abbott, Introduction to Chemical Engineering Thermodynamics, 7th ed., McGraw-Hill, 2005.
4. J.M. Prausnitz, R.N. Lichtenthaler and E.G. Azevedo, Molecular Thermodynamics of Fluid-Phase Equilibria, 3rd ed., Prentice Hall, 1998.

CL246: Heat Transfer [2 1 0 6]

Course objectives:
At the completion of this course student should be able to mathematically model heat transfer problems and solve them using analytical or numerical methods. A primary objective will be to be able to identify the type of heat transfer model that needs to be applied and solved.

Contents:
(1) Introduction: first law, origins, analysis; (2) Conduction: A quick review of conduction - 1D and 2D, Planar surface, Series, Spherical shell. Internal heat source. Extended surfaces. Unsteady state conduction. Numerical methods; (3) Heat exchangers: principles of process design LMTD, e ectiveness-NTU, Details of Heat Exchangers: Types such as shell and tube, plate, double pipe etc, Internal details in a heat exchanger (Ba es, passes on shell and tube side, etc), Operational issues in a Heat Exchanger (Fouling and Clogging, corrosion), Heuristics in Heat Exchangers, Kern Method, Bell-Delaware Method; (4) Convection: Natural and forced convection. Boundary layers. Forced convection- internal and external flow, in noncircular sections, in spherical particles. Film and overall heat transfer coe cients. Convection with phase change: boiling (pool and forced convection boiling) and film condensation; (5) Radiation: Black and gray body radiation. Exchange between surfaces. View factors.

Texts/References

1. Incropera, F.D. and DeWitt, D.P. 2006, 5th edition, Fundamentals of Heat and Mass Transfer, Wiley, New York.
2. Lienhard IV, J.H. and Lienhard V, J.H. 2001. A Heat Transfer Textbook, 3rd Edition, Phlogiston Press, Cambridge, Massachusetts.
3. Process Heat Transfer, Hewitt, G.F., Shires, G.L., Bott, T.R., Begell House Publishers, 1994.

Additional References:

4. McCabe, W.L., Smith, J. and Harriott, P. 1993. Unit Operations of Chemical Engineering, 5th Edition, Tata McGraw Hill, New Delhi.
5. Holman, J.P. 1986. Heat Transfer, 6th Edition, McGraw Hill, New Delhi.
6. Kern, D.Q. 1965. Process Heat Transfer, McGraw Hill, New Delhi.
7. Bird, R.B., Stewart, W.E. and Lightfoot, E.N. 1960. Transport Phenomena, Wiley, New York.
8. Coulson, J.M. and Richardson, J.F. 1996. Chemical Engineering, Vol. 1: Fluid Flow, Heat Transfer and Mass Transfer, 5th Edition, Butterworth-Heinemann, Oxford.

CL202: Introduction to Data Analysis [3 1 0 8]

(1) Descriptive statistics and data visualization: quantities frequently used to describe data (mean, median, mode, range, variance), Chebyshev's inequalities, correlation, data visualization tools/techniques such scatter plots, stem and leaf plots, histograms, quantiles, pie charts, use of dynamically changing plots to visualize evolving data; (2) Random variables and ex-pectations: discrete and continuous random variables, probability density/mass function, cumulative distribution function, conditional probability, Bayes rule, joint density, marginal density, expectation, moments, moment generating functions, special discrete random variables (bernoulli, binomial, geometric, negative binomial, poisson), special continuous random variables (exponential, gaussian, chi-squared, t, F); (3) Distribution of Sampling Statistics: sample mean and its distribution, sample variance and its distribution, central limit theorem; (4) Parameter

Estimation and Confidence Intervals: maximum likelihood estimation, properties of estimators, concept of estimators as random variables, concept of confidence intervals for parameters based on estimators, confidence intervals on mean and variance of normal distribution for various cases, con-fidence intervals on di erence of means of normal distributions, confidence interval on success probability p in a binomial distribution; (5) Hypothesis testing: hypothesis testing framework, type I and type II errors, e ect of sample size on these errors, p-value, hypothesis testing for mean of normal distribution for some commonly encountered situations, hypothesis testing for variance of normal distribution, hypothesis testing for equality of means and variances of data coming from two normal distributions, paired t-tests, hypothesis testing on success probability p in a binomial distribution; (6) Regression: linear versus nonlinear regression, minimization of sum of squares of errors in linear regression, least squares estimators of slope and intercept and their properties, confidence intervals and hypothesis tests on slope and intercept, notion of mean response and individual prediction and corresponding confidence and prediction intervals, model adequacy checking using R^2 and residual plots, variable transformations, introduction to nonlinear regression; (7) Design of experiments: factorial design; (8) Introduction to non-parameteric tests for hypothesis testing;

Texts/References

1. Douglas C. Montgomery, G. C. Runger, Applied Statistics and Probability for Engineers, John Wiley and Sons, 2003.
2. Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists, Elsevier, 4th Edition.

CL31x: Mass Transfer I [2 1 0 6]

Principles of Mass transfer: Constitutive laws of di usion; unsteady state di usion; Convective mass transfer. Interphase mass transfer and mass transfer coe cients; Mass transfer theories/models; E ect of chemical reaction on mass transfer. Equilibrium stages and transfer units: number and height of transfer units; stage e ciency. Gas absorption: plate and packed column design; reactive absorption. Distillation: batch distillation, continuous fractionation, other types of distillation (eg azeotropic); introduction to multi-component mixtures.

Texts/References

1. R.E.Treybal, Mass Transfer Operations, 3rd Edition, McGraw Hill, New Delhi, 1983.
2. E.D. Cussler, Di usion - Mass Transfer in Fluid Systems, Cambridge University Press, Cambridge 1984.
3. A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980.
4. C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993.

CL31y: Mass Transfer II [2 1 0 6]

Prerequisite: CL31x Mass Transfer I

Perspective on Unit Operations; Liquid-Liquid extraction; Leaching; Adsorption and Ion-exchange; Simultaneous Heat and Mass Transfer: Humidification and Dehumidification, Design of cooling towers, Drying, Crystallization; Membrane processes: Ultra-filtration and reverse osmosis.

Texts/References

1. R.E.treybal, Mass Transfer Operations, 3rd Edition. McGraw ill. New Delhi. 1983.
2. A.S.Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York. 1980.
3. C.J.Geankoplis, Transport Processes and Unit Operations, 3rd Edition. Prentice Hall. India, 1993.
4. W.L.McCabe, J.Smith and P.Harriot, Unit Operations of Chemical Engineering, 5th Edition, Tata McGraw Hill, India, 1993.

CL4xxA: Process Equipment Selection [2 2 0 4] (half sem course)

Design variations, Selection criteria, process calculations and representative industrial applications for the following will be covered. (1) Pumps: Types of pumps and selection criteria, Typical calculations of a pumping circuit and pump rating, Pump characteristic curves, Cavitation and NPSH. (2) Compression and Expansion: blowers and compressors, Single or multistage compressing, Typical multistage compressor calculations. (3) Furnaces: Types of furnaces, simple 1-D, 2-D heat transfer models of furnaces. (4) Gas-Solid Catalytic Reactors: Fluidized Bed. (5) Evaporator: Multiple E ect Evaporator Design, Optimum number of e ects; Plant Design: PFD, P&ID, Plant Layout, Safety

Texts/References

1. M.S. Peters and K.D. Timmerhaus, Plant Design and Economics for Chemical Engineers, McGraw Hill, 1991.
2. D.F. Rudd and C.C. Watson, Strategy of Process Engineering, John Wiley, 1969.
3. F.C. Jelen and J.H. Black, Cost and Optimization Engineering, McGraw Hill, 3rd ed., 1992.
4. S. Walas, Chemical Process Equipment Selection and Design, Butterworth, 1988.
5. M.V. Joshi, Process Equipment Design, McMillan India, New Delhi, 1976.
6. R.K. Sinnot, An Introduction to Chemical Engineering Design, Pergamon Press, Oxford, 1989.
7. Relevant Design Codes BS, IS and ASME.
8. R. Smith, Chemical Process Design, McGraw Hill, 1995

CL4xxB: Process Equipment Design [2 2 0 4] (half sem course)

(1) Materials for vessel construction,corrosion and mechanical strength criteria, Alloy Steel, Specimen Test, Yield/Ultimate/Proof/Code Stresses, Elastic and Plastic Deformation, Strain Hardening; (2) Pressure vessels, International Pressure Vessel Design Codes, Various shapes of revolution as employed in shell and closure design of pressure vessels, membrane theory or simple free body diagrams, Safety Factors and Allowable Stress Weld Quality Factor, Shape or Y fac-tor, Design Temperature, Design Pressure, Design Life, Corrosion Allowance, Mill Tolerance, Dimensional Standards for Nominal plate thicknesses and pipe size and schedules; (3) Design for vacuum service, External pressure design, Buckling Failure, Iterative thickness calculation using Factor A - Factor B approach in codes, Sti ener interval calculation; (4) Stress field modification and intensification around openings, nozzle reinforcement calculations as per area compensation method

(5) Additional thickness requirement for tall vessels due to gravity induced, wind induced, vibration induced and eccentric loading induced stresses, Multi-thickness design of tall vessels (6) Typical Mechanical Data Sheet (MDS)

Texts/References

1. M.S. Peters and K.D. Timmerhaus, Plant Design and Economics for Chemical Engineers, McGraw Hill, 1991.
2. D.F. Rudd and C.C. Watson, Strategy of Process Engineering, John Wiley, 1969.
3. F.C. Jelen and J.H. Black, Cost and Optimization Engineering, McGraw Hill, 3rd ed., 1992.
4. S. Walas, Chemical Process Equipment Selection and Design, Butterworth, 1988.
5. M.V. Joshi, Process Equipment Design, McMillan India, New Delhi, 1976.
6. R.K. Sinnot, An Introduction to Chemical Engineering Design, Pergamon Press, Oxford, 1989.
7. Relevant Design Codes BS, IS and ASME.
8. R. Smith, Chemical Process Design, McGraw Hill, 1995

CL451: Chemical Process Design [4 0 0 8]

Prerequisite: CL4xxA (Process Equipment Selection), CL4xxB (Process Equipment Design)

Process Design and Development: General Design Considerations; The Hierarchy of Chemical Process Design; The Na-ture of Process Synthesis and Analysis; Reactor networks in process flowsheets: Attainable region; Separation systems in process flowsheets: multicomponent distillation for ideal + non-ideal systems, distillation column sequences, heat integra-tion in distillation columns; Heat exchange networks synthesis and utilities: Energy targets; Introduction to optimization approaches to optimal design, role of simulations in process design; Design under uncertainty and failure tolerance; En-gineering around variations; Introduction to process integration; Essentials of Process Economics: Time value of money, Simple and compound interest, Capital Cost Estimation, Location and Inflation corrections, Capacity exponents of major equipment, Annualized Capital Cost and Capitalized annual cost, Least Annual Cost, Amortization, Depreciation and taxes, Profitability Chart, Return on investment, Payback Period.

Texts/References

1. J. Douglas, Conceptual Design of Chemical Processes, McGraw Hill, 1989.
2. R. Smith, Chemical Process Design, McGraw Hill, New York, 1995.
3. D.F. Rudd and C.C. Watson, Strategy of Process Engineering, John Wiley, 1969.
4. R.K. Sinnot, An Introduction to Chemical Engineering Design, Pergamon Press, Oxford, 1989.
5. L.T. Biegler, E.I. Grossmann, and A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall International Inc. Series in the Physical and Chemical Engg. Sciences, 1997.
6. W.D. Seider and J.D. Seader, Product and Process Design Principles: Synthesis, Analysis and Evaluation, 2nd ed., John Wiley, 2004
7. M.S. Peters and K.D. Timmerhaus, Plant Design and Economics for Chemical Engineers, McGraw Hill, 1991

CL45x: Process Design Project [0 0 6 6]

Prerequisite: CL455 Design Lab

Literature survey and identification of the best process route(s); Conceptual flowsheet design of the selected chemical process; Calculations for linear material and energy balances; Equipment sizing; Design and Simulation; Heat exchanger network; Process Integration; Costing

Texts/References

1. L.T. Biegler, E.I. Grossmann, and A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall International Inc. Series in the Physical and Chemical Engg. Sciences, 1997.
2. Peters Max, Timmerhaus Klaus, West Ronald, Plant Design and Economics for Chemical Engineers, McGraw-Hill Science/Engineering/Math; 5 edition, 2002.
3. Michael F. Doherty and Michael F. Malone, Conceptual Design of Distillation Systems, Mcgraw-Hill Chemical Engineering Series, McGraw-Hill Education, 2001.
4. Seider Warren D., Seader J. D. and Lewin Daniel R., Product and Process Design Principles: Synthesis, Analysis, and Evaluation, Wiley, 2003.
5. Seader J. D., Henley Ernest J., Roper D. Keith, Separation Process Principles , Wiley, 2010.