S.No	New Course code	Name of Course	L-T-P-C	Proposed Level (UG/PG)
1	CL 801	Advanced chemical engineering thermodynamics	3-0-0-6	PG
2	CL 802	Computational Techniques for Multiphase Flows	3-0-0-6	PG
3	CL 803	Advanced separation processes	3-0-0-6	PG
4	CL 601	Seminar	0-0-4-4	PG

1	**Title of the course** (L-T-P-C)	**Advanced Chemical Engineering Thermodynamics (3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Review of classical thermodynamics (1st and 2nd law, Thermodynamic functions, Maxwell`s relations, Equations of State for gases, Theory of corresponding states, Phase rule, Mixtures, Gibbs-Duhem relation), Classical mechanics and quantum mechanics, Canonical, Microcanonical and Grand Canonical ensemble, Boltzmann, Fermi-dirac and Bose Einstein statistics, Fluctuations, Monoatomic and Diatomic Gases, Introduction to Classical Statistical Mechanics, Phase space, Liouville equation, Crystals, Intermolecular forces and potential energy functions, imperfect monoatomic Gases, Molecular theory of corresponding states, Introduction to molecular simulations, Mixtures, Partial molar properties, Gibbs-Duhem equations, Fugacity and Activity coefficients, Ideal and Non-ideal solutions, Molecular theories of activity coefficients, Lattice models, Multiphase multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Chemical equilibrium and combined phase and reaction equilibria.
4	**Texts/References**	**1.** Y V C Rao, "Chemical Engineering Thermodynamics", Universities Press,1997. **2.** Stanley I. Sandler; "Chemical, Biochemical, and Engineering Thermodynamics 5th Edition", Wiley, 2017. **3.** J.M. Smith, H.C. Van Ness, M.M. Abott, M.T. Swihart, “Introduction to Chemical Engineering Thermodynamics 9th Edition", McGraw-Hill, 2019. **4.** McQuarrie D.A, “Statistical Mechanics”, Viva Books Private Limited, 2018. **5.** Hill Terrel, An Introduction to Statistical Thermodynamics, Dover, 1960. **6.** Allen MP, Tildesley DJ, Computer simulation of liquids, Oxford, 1989. **7.** Callen, HB. Thermodynamics and an Introduction to Thermodstatics, 2nd Edition, John Wiley and Sons, 1985. **8.** Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular thermodynamics of fluid-phase Equilibria (3rd edition), Prentice Hall Inc., New Jersey,1996.

1	**Title of the course** (L-T-P-C)	**Computational Techniques for Multiphase Flows (CTMF)** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**I**. Introduction to Multiphase Flows: Basics of Multiphase Flows and Classifications; Characteristics of Multiphase Flows; Applications of Multiphase Flows. Revisit of Governing Equations for Multiphase Flows: Conservation Equations, Mass Conservation; Momentum Conservation; Energy Conservation **II.** Multiphase Flow Simulation Techniques: Introduction to interphase capturingmethods; Volume of Fluid (VOF) method; Surface tension modeling; Interfacereconstruction and advection schemes; Static and dynamic contact angles; Level Set (LS) method; Coupled Level-Set and Volume of Fluid(CLSVOF). **III**. Eulerian–Eulerian and Eulerian-Lagrangian models; Kinetic Theory of Granular Flows (KTGF); Restitution and Specularity Coefficients; Drag models for multiphase systems; Two-Fluid Model (TFM); Mixture model; Eulerian-Lagrangian Two-Fluid Model framework. **IV**. Demonstration and Hands-on simulations: Modelling of multiphase problemsusing commercial or open-source software such as packed bed and fluidizedbed reactors; Gas-liquid bubble column and gas–liquid–solid three-phase bubble column (i.e., slurry bubble column); Droplet and bubbly flows; Sediment transport in pipelines and bends. **V**. Case Studies and Projects: Real-world examples of multiphase flow problemsand recent research articles on two-phase and three-phase flows i.e., gas- particle and liquid-particle flows; Free surface flows
4	**Texts/References**	**1**. Yeoh, Guan Heng, and Jiyuan Tu. Computational techniques for multiphase flows. Butterworth-Heinemann, 2019. **2**. Tryggvason, Grétar, Ruben Scardovelli, and Stéphane Zaleski. Direct numerical simulations of gas–liquid multiphase flows. Cambridge university press, 2011. **3**. Crowe, Clayton T., et al. Multiphase flows with droplets and particles. CRC press, 2011. **4**. Anderson, John David, and John Wendt. Computational fluid dynamics. Vol. 2006. New York: McGraw-Hill, 1995. **5**. Versteeg, Henk Kaarle, and Weeratunge Malalasekera. An introduction to computational fluid dynamics: the finite volume method. Pearson education, 2007. **6**. Ranade, Vivek V. Computational flow modeling for chemical reactor engineering. Vol. 5. Academic press, 2002.

1	**Title of the course** (L-T-P-C)	**Advanced separation processes** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	CL203, ME301 (Heat and Mass Transfer) or equivalent
3	**Course content**	Review of conventional processes and recent advances in separation process, analyse the thermodynamics, advanced mass transfer and diffusion theories underpinning the multi-component separation processes. Membranes: adsorption, permeation, Pervaporation, Dialysis and Electrodialysis, Reverse Osmosis, Ultrafiltration, Microfiltration. Apply conceptual procedures for the design of next generation separation devices, combine the simulation tools and analysis methods to determine the energy efficiency, cost-effectiveness and sustainability of design solutions.
4	**Texts/References**	**Textbooks** **1**. Rousseau, R. W. (1987), Handbook of Separation Process Technology, John Wiley & Sons. **2**. Humphrey, J. L. and Keller, G. E., (1997), Separation Process Technology, McGraw- Hill, NY. **3**. Norman, N, Li, Anthony G. Fane, Winston Ho, W. S., Matsuura. T. (2008), Advanced Membrane Technology and Applications, Wiley. **Reference Books** **1**. Kister, H. Z., (1992), Distillation Design, McGraw-Hill. **2**. Ernest J. H., Seader J. D., D. Keith Roper (2011), Separation Process Principles, 3rd Edition Wiley. **3**. Taylor, R., Krishna, R. (1993), Multicomponent Mass Transfer, John Wiley & Sons. **4.** Swain A., Patra H., Roy G. K. (2010) Mechanical Operations, McGraw Hill Education.