# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-101 **Course Title:** Computer Programming
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the fundamentals of applied programming algorithms and language for chemical engineering applications.

10. **Details of the Course**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | Fundamentals of The Python Language: Client-side vs server side programming; Downloading and installing Python; Downloading and Installing Jupyter Notebook; Writing a program using Jupyter Notebook. | 2 |
| 2. | Python programs: printing; basic data types; Arithmetic operators; Boolean values; Comparison operators; Strings; Casting; Downloading and installing IDLE; using the IDLE Shell; Renaming python scripts; Adding comments; Using a variable; Boolean operators; variable substitution; combining variables; getting user input; the if…elif…else statement; multiple if conditions; Checking user input. | 3 |
| 3. | Creating a list, updating a list, types of loops, executing loop a number of times, iterating over a list, iterating over strings, for loops using range, repeatedly executing code using a condition, waiting for user input, exiting a loop using break, exiting a loop using continue, nested loops, what is a function, built-in functions, user defined functions, docstrings, executing order, the main function, | 3 |
| 4. | About PyCharm, Downloading and installing PyCharm, reusing code, a review of lists, more list operations, list functions, slicing lists, string vs lists, slicing string, split and join, creating a tuple, creating a set, iterating over and updating a set | 3 |
| 5. | Creating a dictionary, key::value pairs, updating a dictionary, opening a file, basic of file open method modes, reading a file, newline characters, writing to a file, closing a file. | 3 |
| 6. | Introduction to Python libraries: numPy, Pandas, Matplotlib and SciPy, etc. Using import command. Using numPy library to perform matrix algebra, recursive iterative algorithms, etc. | 6 |
| 7. | Using SciPy library in Python programs to perform Integration, Optimization, Interpolation, Fourier transforms, Signal processing, Linear algebra, Sparse eigenvalue problems, Statistics, Image processing and File I/O; Review of special functions in SciPy library, | 9 |
| 8. | Data analysis and interpretation, linear regression, polynomial regression, non-linear regression and symbolic regression for single and multi-variable datasets | 9 |
| 9. | Basic applications to chemical engineering problems | 4 |
| | **Total** | **42** |

**11. Suggested Books:**

| S.No. | Name of Books/Authors/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Python Crash Course – A Hands-on, Project based Introduction to Programming, Eric Matthes, No Starch Press, US, 3rd Edition | 2023 |
| 2. | Head First Python: A Brain Friendly Guide, Paul Barry, 2nd Edition | 2016 |
| 3. | Python Programming: An Introduction to Computer Science, John M Zelle, 3rd Edition | 2016 |
| 4. | Python in a Nutshell, Alex Martelli and Anna Martelli Ravenscroft, Steve Holden and Paul McGuire, 4th Edition | 2023 |
| 5. | Fluent Python: Clear, Concise and Effective Programming, Luciano Ramalho, 2nd Edition | 2022 |

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHE-101 **Course Title:** Energy Engineering
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration(Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** ESC
8. **Pre-requisite:** Nil
9. **Objective:** To impart an understanding of different resources of energy, their exploration, conversion, energy audit, and conservation.

10. **Details of the Course:**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction:** Classification of energy sources; Energy conversion-transmission and storage; Energy consumption pattern in various sectors; Carbon footprint and economics of various energy sources and conversion processes: National and International policies on energy | 5 |
| 2. | **Coal**: Classification and properties; Proximate and ultimate analyses; Heating value; Electricity generation from coal; Clean coal technologies, Carbon footprint and concerns | 4 |
| 3. | **Liquid & Gaseous Fuels:** Origin and processing, various type of liquid (Diesel, Petrol, etc.) and gaseous fuels (CNG, LNG, LPG); Properties and handling; carbon footprint and concerns; Biodiesel, bioethanol & biomethanol; Government policies on blending; Unconventional gas resources including shale gas, coal bed methane and natural gas hydrates | 7 |
| 4. | **Biomass energy**: Biomass; Characterization of biomass; Densification of biomass, Biomass conversion to solid, liquid, and gaseous fuels using thermochemical and biochemical routes; Biomass blending with coal; Government policies and challenges | 6 |
| 5. | **Solar energy:** Solar or photovoltaics cells; Components and type of the solar cells; Recent development & challenges; Solar thermal energy system; Solar space heating and cooling; Solar based chemical reactors | 4 |
| 6. | **Other Energy Resources:** Wind, hydro, geothermal, nuclear, and tidal energy systems; Development and challenges | 4 |
| 7. | **Hydrogen Energy:** National Hydrogen Policy; Green, blue and grey hydrogen; Hydrogen storage and utilization; Hydrogen-based fuel cells; challenges and concerns | 4 |
| 8. | **Energy Storage and Conversion:** Fuel Cells; Batteries; Integration of renewable energy with existing grids; Challenges and government policies | 3 |
| 9. | **Energy audit & Conservation:** Mapping of distribution of energy supply and demand and identification of energy intensive areas; Energy conservation using smart electronics; Process integration and waste heat recovery. | 5 |
| **Total** | | **42** |

## 11. Suggested Books:

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Balasubramanian Viswanathan, Energy Sources Fundamentals of Chemical Conversion Processes and Applications, Elsevier | 2016 |
| 2. | Twidel, J. and Tony W., Renewable Energy Resources, Second Edition, Taylor & Francis | 2006 |
| 3. | Kreith F., Goswami D. Y., Energy Management and Conservation, CRC Press | 2008 |
| 4. | Sukhatme S., J Nayak J., Solar Energy: Principles of Thermal Collection and Storage, 3/ed, Tata McGraw-Hill Publishing Company Ltd | 2008 |
| 5. | Harker J.H. and Backhusrt J.R., Fuel and Energy, Academic Press Inc | 1981 |
| 6. | Miller Bruce G., Coal Energy Systems, Elsevier Academic Press, Paris | 2005 |

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHE-102 **Course Title:** Introduction to Process Technology
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** ESC
8. **Pre-requisite:** Nil
9. **Objective:** To impart knowledge of process and product development of multiple chemical industries and understand how things are made in the engineering world.

10. **Details of Course:**

| S.No. | Contents | Contact hours |
|---|---|---|
| 1. | **Introduction to process technology:** Overview of different industries and understanding of the integration of different disciplines for the development of a process or product | 4 |
| 2. | **Semiconductor technology:** Manufacturing of semiconductors and devices, microchip technology and chemical vapour deposition | 6 |
| 3. | **Polymers and synthetic fibres:** Polyethylene, polyvinyl chloride, styrene butadiene rubber, polybutadiene, polyester, polyamide, acrylic fibre and viscose rayon | 6 |
| 4. | **Paper technology:** Raw materials, pulping processes, stock preparation and paper making | 5 |
| 5. | **Particle technology:** Powders, tablet and pellet manufacturing, granulation, grain storage and handling | 5 |
| 6. | **Production of paints, lubricants and coatings:** Classifications, production methodologies, spraying techniques | 5 |
| 7. | **Petroleum refining:** Origin, occurrence and characteristics of crude oil, distillation, residue upgradation and secondary conversion processes. | 5 |
| 8. | **Production of petrochemicals:** Olefin and aromatic production, methanol, formaldehyde, ethylene oxide, ethylene glycol, acetaldehyde, acetic acid, propylene oxide, propylene glycol, nitrobenzene | 6 |
| | **Total** | **42** |

**11. Suggested Books**

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Austin G. T., “Shreve’s Chemical Process Industries”, Fifth edition, Tata McGraw Hill, NY. | 2012 |
| 2. | Gopala Rao M. and Marshall Sittig, “Dryden’s Outlines of Chemical Technology for the 21st Century”, Affiliated East –West Press, New Delhi. | 2002 |
| 3. | Mall I. D., “Petrochemical Process Technology”, Macmillan India Ltd., New Delhi | 2007 |
| 4. | Xiao, Hong, “Introduction to Semiconductor Manufacturing Technology”, SPIE Press. | 2013 |
| 5. | Seville, J.P.K., and Wu, C.-Y., “Particle Technology and Engineering: An Engineer’s Guide to Particles and Powders: Fundamentals and Computational Approaches”, Butterworth Heinemann. | 2016 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-201 **Course Title:** Heat Transfer
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide basic knowledge about heat transfer and its processes used in chemical process industries.

**10. Details of the Course**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction**: Heat transfer modes, rate equations | 2 |
| 2. | **Conduction**: Use of extended surfaces, one-dimensional steady state conduction, thermal insulation materials for cold and hot applications and thickness calculations, introduction to transient conduction, Biot number, use of Heisler Charts | 6 |
| 3. | **Convection:** Concept and significance of boundary layer, boundary layer similarity and analogy, convection heat transfer coefficients, free and forced convection, empirical correlations-internal and external flows | 7 |
| 4. | **Heat exchangers:** Types and selection, overall heat transfer coefficient, parallel and counter current flow, LMTD, $F_t$ correction factor, analysis and design using effectiveness-NTU method | 7 |
| 5. | **Radiation:** Mechanism of radiation and its laws, black and grey body behavior, shape factors-determination using equations and charts, relationship between shape factors, heat transfer between non-black bodies, concept of surface and space-resistance with concept of insulated and large surfaces, use of radiation shields, radiation through absorbing and transmitting gases | 5 |
| 6. | **Boiling:** Characteristics, nucleate pool and forced convection boiling, boiling mechanism and curve, heat transfer correlations, heat pipes | 4 |
| 7. | **Condensation:** Mechanism and types of condensation of vapor with and without non-condensable gases, Nusselt equation for filmwise condensation on vertical surfaces and its extension to inclined and horizontal surfaces and tubes, condensation number, film condensation inside a horizontal tube | 5 |
| 8. | **Evaporation and Evaporator:** Classification and use of evaporators in process industries, effect of boiling point rise and hydrostatic head on evaporator performance, liquor flow sequences, calculations for multiple effect evaporator system | 6 |
| | **Total** | **42** |

## 11. Suggested Books

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Y.A. Cengel and A.J. Ghajar, Heat and Mass Transfer – Fundamentals and Applications, 5th edition, McGraw Hill | 2015 |
| 2. | Binay K. Dutta, "Heat Transfer-Principles and applications", PHI Learning (P)Limited | 2018 |
| 3. | R.P. Chhabra and V. Shankar, "Coulson and Richardson's Chemical Engineering. Vol 1B: Heat and Mass Transfer: Fundamentals and Applications", 7th edition, Elsevier | 2018 |
| 4. | A.M. Flynn, T. Akashige and L. Theodore, "Kern's Process Heat Transfer", 2nd edition, Wiley | 2019 |
| 5. | S.P. Venkateshan, "Heat Transfer", 3rd edition, Springer | 2021 |
| 6. | C.H. Forsberg, "Heat Transfer – Principles and Applications", Academic Press | 2021 |
| 7. | C. Balaji, B. Srinivasan and S. Gedupudi, "Heat Transfer Engineering – Fundamentals and Techniques," Academic Press | 2021 |

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-202 **Course Title:** Chemical Reaction Engineering
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide comprehensive knowledge of reaction engineering and Chemical reactors.
10. **Details of the Course**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction**: Review of rate equations -Reaction rate, order, Molecularity and rate constant | 2 |
| 2. | **Ideal Reactors:** Homogeneous reactions in ideal reactors<br>**Kinetics of homogeneous reactions**: Concentration and temperature dependent term of a rate equation, searching for a mechanism<br>**Interpretation of kinetic data of batch reactors**: Constant volume and variable volume batch reactors, Integral and differential methods of analysis of data of uni, bi and tri-molecular irreversible reactions, Reversible reactions, homogeneously catalyzed reactions, Estimation of rate constants and its temperature dependence | 7 |
| 3. | **Design for single reaction**: Design equation for single reaction systems using batch and semi-batch reactors, CSTR, PFR, and recycle reactor, autocatalytic reactions, reactor choice for single reaction | 6 |
| 4. | **Design for multiple reactions:** parallel and series reactions, quantitative treatment of product distribution and of reactor size for different types of ideal reactors, selectivity and yield factors, reactor choice for multiple reactions | 6 |
| 5. | **Non-isothermal operation and stability of reactors:** Non-isothermal design of ideal reactors, energy balance in reactors, adiabatic and non-adiabatic reactors, hot spot in tubular reactor, auto thermal process, steady state multiplicity optimal temperature progression for first order reversible reaction | 5 |
| 6. | **Non-ideal flow:** Residence time distribution (RTD) theory, role of RTD in determining reactor behavior, age distribution (E) of fluid, experimental methods for finding E, relationship between E and F curves, models for non-ideal flow-zero parameter (segregation) model, single parameter models (axial dispersion), performance estimation of reactor using reactor models. | 8 |
| 7. | **Solid and catalytic reactions:** Solid reactions-shrinking core model, catalytic reactions-homogeneous and heterogeneous, steps in solid catalyzed reaction, rate limiting steps, effect of external resistance, effect of diffusion on reaction, Thiele modulus and effectiveness factor, performance equations for catalytic reactors (packed bed), product distribution in multiple reactions | 8 |
| | **Total** | **42** |

## 11. Suggested Books

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Levenspiel O, “Chemical Reaction Engineering”, 3rd Ed. Wiley-India | 2008 |
| 2. | Fogler H.S. “Elements of Chemical Reaction Engineering,” 4th Ed. Prentice Hall of India | 2014 |
| 3. | Butt J.B., “Reaction Kinetics and Reactor Design”, 2nd Ed., CRC Press | 2000 |
| 4. | Froment G.F., Bischoff K.B., De Wilde J.D., “Chemical Reactor Analysis and Design”, 3rd Ed., John and Wiley and Sons, Inc | 2011 |
| 5. | Doraiswamy L.K., and Uner D., “Chemical Reaction Engineering: Beyond the fundamentals”, CRC Press | 2013 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-203 **Course Title:** Chemical Engineering Thermodynamics
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To apply the laws of thermodynamics in solving problems related to flow processes and phase equilibrium of heterogeneous and reacting systems.

10. **Details of Course:**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction:** Thermodynamic system, surroundings, state, properties, equilibrium, heat and work | 4 |
| 2. | **Properties of pure simple compressible substance:** P-V-T surface, P-V, T-V and T-P diagrams, Equations of state for ideal and real gases and use of thermodynamic tables | 4 |
| 3. | **Laws of thermodynamics:** Energy balance for closed and open system, Steady and Transient Processes. Second law and entropy, Carnot Engine, entropy change for closed and open systems. | 8 |
| 4. | PVT behavior of mixtures, Estimation of thermodynamic properties and charts. | 4 |
| 5. | **Thermodynamic properties of mixtures or solutions:** Property relationships for systems of variable composition, chemical potential, partial molar properties, fugacity and fugacity coefficients-pure species and species in a mixture, fugacity in ideal solutions, activity coefficients, excess properties | 8 |
| 6. | **Phase Equilibria:** VLE-qualitative behavior, Duhem's theorem, simple models for VLE (Roult's law, modified Raoult's law etc.). Liquid properties from VLE. VLE calculations at low and high pressures, analysis of multicomponent, multiphase systems | 7 |
| 7. | **Chemical Reaction Equilibria:** Reaction coordinate, application of equilibrium criteria to chemical reactions, standard Gibbs energy change and the equilibrium constant, effect of temperature on equilibrium constant, evaluation of equilibrium constant and composition. Calculation of equilibrium compositions for single reactions, phase rule and Duhem's theorem for reacting systems | 7 |
| | **Total** | **42** |

11. **Suggested Books**

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Smith J.M., Van Ness H.C. and Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 7$^{th}$ Ed., McGraw Hill | 2005 |
| 2. | Sandler S.I., "Chemical, Biochemical and Engineering Thermodynamics", 4$^{th}$Ed., John Wiley | 2006 |
| 3. | Kyle B.G., "Chemical and Process Thermodynamics", 3$^{rd}$ Ed., Prentice Hall | 1999 |
| 4. | Narayanan K.V., "Chemical Engineering Thermodynamics", Prentice Hall | 2007 |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-301 **Course Title:** Computer Applications in Chemical Engineering
2. **Contact Hours:** **L:** 0 **T:** 0 **P:** 4
3. **Examination Duration (Hrs.):** **Theory:** 0 **Practical:** 0
4. **Relative Weightage:** **CWS:** 0 **PRS:** 50 **MTE:** 0 **ETE:** 0 **PRE:** 50
5. **Credits:** 2 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide knowledge of numerical methods using computer programming to solve chemical engineering problems.

10. **Details of Course:**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction to mathematical modeling and simulations:** Introduction of Computational tool(s) for modeling and simulations | 4 |
| 2. | **Solution of non-linear algebraic equations:**<br>Practical 1: Equation of States & Vapor liquid equilibria<br>Practical 2: Chemical reaction equilibria | 8 |
| 3. | **Solution of linear algebraic equations:**<br>Practical 3: Mass Balances with/without Recycle Streams<br>Practical 4: Simultaneous Mass and Energy Balance | 8 |
| 4. | **Curve fitting and Polynomial Interpolation:**<br>Practical 5: Regression analysis of single- and multi- variable systems<br>Practical 6: Reaction kinetics determination | 8 |
| 5. | **Optimization in Chemical Engineering:**<br>Practical 7: Optimization of CSTR/PFR train for conversion maximization<br>Practical 8: Optimization of non-isothermal CSTR/PFR with multiple reactions | 8 |
| 6. | **Ordinary Differential Equations**:<br>Practical 9: Batch reactor with/without mass transfer<br>Practical 10: Isothermal/Non-isothermal Plug Flow Reactors – single ODE | 8 |
| 7. | **Partial Differential Equations**:<br>Practical 11: Unsteady state chemical reactors<br>Practical 12: Fluid flow in 1D/2D/3D problems<br>Practicals 13-14: Heat and Mass Transfer in 1D/2D/3D problems | 12 |
| | **Total** | **56** |

**11. Suggested Books:**

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Chapra, S. C., Canale, R. P., “Numerical Methods for Engineers”, $8^{th}$ Ed., Tata McGraw-Hill, New Delhi | 2021 |
| 2. | Cutlip M. B. and Shacham M., “Problem Solving in Chemical and Biochemical Engineering with POLYMATH, EXCELL and MATLAB”, $2^{nd}$ Ed., Prentice Hall | 2008 |
| 3. | Gupta, S.K., “Numerical Methods for Engineers”, $2^{nd}$ Edition, New Age International Publishers | 2010 |
| 4. | Beers, K., “Numerical Methods for Chemical Engineering: Applications in MATLAB”. New York, NY: Cambridge University Press | 2006 |
| 5. | Finlayson, B.A., “Introduction to Chemical Engineering Computing”, John Wiley & Sons, Inc., Hoboken, New Jersey | 2012 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-305 **Course Title:** Process Equipment Design*
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 4 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Heat Transfer and Mass Transfer
9. **Objective:** To provide knowledge about design principles of heat and mass transfer equipment involved in chemical plants.

10. **Details of Course:**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Pressure Vessel:** Introduction of codes for pressure vessel design, classification of pressure vessels as per codes. Thickness of cylindrical and spherical shells under internal and external pressure; Selection and design of closures and heads; Compensation of openings. | 8 |
| 2. | **Shell & Tube Heat Exchangers:** Overall heat transfer coefficient; fouling factors, Design procedure of shell & tube heat exchangers – construction details, design details (Kern's method and Bell's method, HTRL method) | 11 |
| 3. | **Condensers:** Design of condensers, heat transfer coefficient correlations for condensation inside and outside of tubes of the vertical and horizontal condensers, pressure drop in condensers. | 4 |
| 4. | **Reboilers, Evaporators and Crystallizer**: Selection of reboilers; Design of reboilers, evaporators and crystallizers. | 7 |
| 5. | **Distillation Column:** Basic design consideration of distillation column, degreeof freedom analysis; Design consideration of multicomponent distillation, plate efficiency, tray hydraulics of sieve and valve-trays. | 9 |
| 6. | **Packed Columns:** Type of packing, Design of packed column-packed bedheight, column diameter, column internals. | 3 |
| **Total** | | **42** |

*** Note:** This is an OPEN BOOK EXAMINATION. The students are allowed to consult IS Codes, Text books, Reference books and bound lecture notes certified by the examiner concerned.

**11. Suggested Books:**

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Towler G. and Sinnott R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", 4th Ed., Butterworth-Heinemann. | 2012 |
| 2. | Seader J. D. and Henley E. J., "Separation Process Principles", 2nd Ed., Wiley-India. | 2006 |
| 3. | Serth R. W., "Process Heat Transfer: Principles and Applications",Academic Press. | 2007 |
| 4. | Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 2 and 3, 3rd Ed., Gulf Professional Publishing-Butterworth- Heinemann. | 1997 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-302 **Course Title:** Process Instrumentation and Control
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 2/2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 15-30 **PRS:** 20 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To impart the knowledge of process dynamics, instrumentation, and control systems in the chemical and allied industries

10. **Details of the Course:**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction:** Basics of process dynamics, instrumentation and control, review of Laplace transforms methods and dynamic model building of simple systems. | **4** |
| 2. | **Building blocks of an Instrument:** Instrument performance parameters, sensors, transducers, amplifier, signal conditioner, signal isolation, signal transmitter, display, data acquisition modules, I/O devices, signal converters and interfaces. | **4** |
| 3. | **Process Instrumentation:** Working principles, merits and demerits of transducers/instruments employed for the measurement of flow, level, force, pressure, temperature, density, viscosity, humidity, pH value and turbidity. | **5** |
| 4. | **Linear Open Loop System:** Physical examples of first order systems and their response for step, impulse and sinusoidal inputs, linearization of non-linear models, response of first order system in series, examples of second order systems and their responses, estimation of system parameters. | **7** |
| 5. | **Linear Closed Loop System:** The control system and its elements, closed loop transfer functions, transient response of simple control systems, concept of stability, Routh-Hurwitz test for stability. | **6** |
| 6. | **Controllers:** Modes of control action, PI, PD, PID controllers, control system and its closed loop transfer function. Root locus treatment, response from root locus and its application to control system design. | **6** |
| 7. | **Frequency Response:** Introduction to frequency response, Bode diagrams, Bode Stability criterion, control system design by frequency response, use of gain and phase margins. | **4** |
| 8. | **Control Applications:** Controller tuning rules, control of complex chemical processes and equipment, control valve sizing, feed-forward control, ratio control, inferential control, cascade control and internal model control. | **6** |
| **Total** | | **42** |

**11. Suggested Books:**

| S.No. | Name of Authors/Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Coughanowr D. R. and LeBlanc S., "Process System Analysis and Control", 3rd Edition, McGraw Hill. | 2008 |
| 2. | Stephanopoulos G., "Chemical Process Control – An Introduction to Theory and Practice", Prentice Hall of India | 1990 |
| 3. | Seborg D. E., Edgar T. F. and Mellichamp D. A., "Process Dynamics Control", 2nd Edition, John Wiley. | 2004 |
| 4. | Bequette B. W., "Process Control – Modeling, Design and Simulation", Prentice Hall of India | 2003 |
| 5. | Dunn W. C., "Fundamentals of Industrial Instrumentation and Process Control", Tata McGraw Hill. | 2009 |
| 6. | Nakra B. C. and Chaudhary K. K., "Instrumentation, Measurements and Analysis", 2nd Edition, Tata McGraw Hill. | 2004 |
| 7. | Andrew W. G., "Applied Instrumentation in the Process Industries", Vol. I, 3rd Edition Gulf Publishing Company. | 1993 |
| 8. | Johnson C., "Process Control Instrumentation Technology", 8th Edition, Prentice Hall | 2005 |

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

1. **Subject Code:** CHC-304 **Course Title:** Plant Design and Process Economics
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 3 **6. Semester:** Spring **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide the fundamentals of economics, scale-up methods, and design strategies of plants.
10. **Details of the Course:**

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction:** Process Design, development, general design considerations, health, safety hazard, and its control, Cost and asset accounting | 3 |
| 2. | **Time Value of Money and Profitability Analysis:** Methods without and with time value of money; Interest and investment cost, type of interest, nominal and effective interest rates, continuous interest, present worth and discount annuities, cost due interest on investment, source of capital. Interest; Compounding and discounting factors; Annuity and perpetuity; Loan payments; Cash flow pattern: Discrete cash flow, continuous cash flow. Economic problems: scarcity and choice, circular flow of economic activity, national income concepts and measurement. | 8 |
| 3. | **Depreciation**: Types of depreciation, services life, salvage value, present value, Methods for determining depreciation: Straight line, declining balance, double declining balance, sum-of-the-years-digit, sinking fund; Amortization. | 6 |
| 4. | **Analysis of Cost Estimates**: Cost concepts- explicit and implicit cost, fixed and variable cost, opportunity cost, sunk costs, cost function, cost curves, cost and output decisions. Factors affecting investment and production costs; Capital investment; Types of capital cost estimates; Methods for estimating capital investment; Estimation of revenue; Alternative investment methods; Inflation; Methods for replacements. Estimation of total product cost; Gross profit; Net-profit and cash flow; Contingencies. | 8 |
| 5. | **Taxes and insurances:** Type of taxes: federal income taxes, capital-gain tax, types of insurance, self-insurance, Business-interruption insurance, Marine and transportation insurance. | 4 |
| 6. | **Scale-Up**: Principle of similarity; Dimensional analysis; Similarity criteria and scale equations for important equipment. Factor in equipment scale-up and design, safety factor. | 5 |
| 7. | **Techno-economic Feasibility:** Plant location; Site selection and preparation; Plant layout and installation. Raw material and product market analysis; Flow diagrams: BFD, PFD, P&ID; Techno-economic analysis. Theory of production-production function, law of variable proportions, laws of returns to scale, production optimization, least cost combination of inputs, isoquants. | 8 |
| | **Total** | **42** |

**11. Suggested Books:**

| S.No. | Name of Authors/Books/ Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Peters, M. S., Timmerhaus, K. D. and West, R. E., "Plant Design and Economics for Chemical Engineers", McGraw Hill, 5th Edition. | 2002 |
| 2. | Towler, G. and Sinnott, R. K., "Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design", Butterworth-Heinemann, 2nd Edition. | 2012 |
| 3. | Couper, J. R., "Process Engineering Economics (Chemical Industries)", CRC Press, 1st Edition. | 2003 |
| 4. | Zlokarnik, M., "Scale-up in Chemical Engineering", Wiley-VCH, 2nd Edition. | 2006 |

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHC-204 **Course Title:** Mass Transfer

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PCC

**Course Outline**: Molecular diffusion - fluids and solids, Interphase mass transfer, Convective mass transfer, Mass transfer coefficients, Gas Absorption, Kremser Equations, Tray efficiency, Height of Packing, HETP, Distillation, Reflux ratio, Fenske Equation, McCabe-Thiele Method, Packed Bed Tower, $HT_{OG}$, $NT_{OG}$, HETP, Humidification, Cooling tower, Extraction, Adsorption, Drying.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-323 **Course Title:** Transport Phenomena

**L-T-P:** 3-0-0 **Credits:** 3 Subject Area: **PEC**

**Course Outline**: Molecular Transport Phenomena, Non-Newtonian Fluids, Equations of Change Under Laminar Flow Conditions, Turbulence Phenomena, Methods of Analysis of Transport Problems, Convective Transport, Transport Past Immersed Bodies.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHO-101 **Course Title:** Computational Fluid Dynamics

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** OEC

**Course Outline**: Philosophy of computational fluid dynamics (CFD), review of equations governing fluid flow and heat transfer, flow models, flow classification, structured and unstructured grids, choice of suitable grid, grid transformation of equations, Finite Difference Method (FDM): discretization of ODE and PDE, approximation for first, second and mixed derivatives, implementation of boundary conditions, discretization errors, Finite Volume Method (FVM): discretization methods, approximations of surface integrals and volume integrals, interpolation and differential practices, implementation of boundary conditions, Case studies using FDM and FVM.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT:** Department of Chemical Engineering

**Subject Code:** CHL-542 **Course Title:** Energy Audit

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course Outline:** Energy Scenario, Energy Conservation Act-2001, Energy and its Forms, Energy Audit and Action Planning, Sankey Diagram, Sensitivity and Risk Analysis, Project Planning Techniques, Energy Efficiency and Climate Change, Energy Monitoring and Targeting, International Agreements, The Kyoto Protocol, Case Studies.

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTER/SCHOOL:** Department of Chemical Engineering

**Subject code:** CHO-103 **Course Title:** Polymer World

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** OEC

**Course Outlines:** Polymer Family: plastic, rubber, fiber (by use), Addition and condensation polymer (by kinetics); natural, semi-synthetic and synthetic (by origin); Thermoplastic and thermosetting (thermal behavior); Crystalline, amorphous and semi-crystalline; Atactic, syndiotectic and isotactic (by disposition of groups in space); domestic and engineering polymers. Polymer Products: Tyre, hose, cable, automotive, Packaging. Construction polymers, different moulded products.

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTER/SCHOOL:** Department of Chemical Engineering

**Subject code:** CHO-105 **Course Title:** Environmental Engineering

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** OEC

**Course Outlines:** Classification of environment; Definition of air, water, solid, and hazardous pollutants and their effects on the environment; Characterization of industrial pollution and its limits based on various sectors and clusters; Various industrial wastewater treatment technologies and their design procedures; Estimation of industrial effluent discharges and their impact on river water; Estimation of carrying capacity of river; Modeling of river.

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHC-205 **Course Title:** Chemical Engineering Lab-I

**L-T-P: 0-0-4** **Credits: 2** **Subject Area: PCC**

**Course outlines:** Impact of Jet, Bernoulli's Theorem, Centrifugal Pump, Reciprocating Pump, Center of Pressure (Hydrostatics), Flow Measurement Methods - Venturimeter, Orificemeter, and Rotameter; Darcy's Law, Reynolds Apparatus, Discharge over Notches, Loss due to Pipe fittings, Characteristics of a Packed Bed, Characteristics of a Fluidized Bed, Plate and Frame Filter Press, Sedimentation, Ball Mill, Elutriator.

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-543 **Course Title:** AI/ML for Computational Fluid Dynamics

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course outlines:** Overview and synergy between AI/ML and CFD, Data Collection and Analysis, Fundaments of Neural Networks, Type of Neural Networks, Machine Learning for data-driven modeling, AI/ML techniques in CFD, Physics-Informed Neural Networks, Turbulence modeling with AI/ML, Practical Implementation and Tools, Project Development.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-544 **Course Title:** Fundamentals of lithium-ion batteries

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course outlines:** Fundamentals of electrochemistry, Electrochemical cells; Primary batteries, secondary batteries (Lead-acid battery, Ni-Cd battery, Ni-MH battery); Basics of Lithium-ion batteries: Working principle, cell components, anode materials, cathode materials, electrolyte, separator, charging, discharging; Manufacturing/Assembly of Lithium-ion cells, formation process, ageing and capacity grading, testing electrochemical performance, safety; form factors, Application of lithium-ion batteries, (potable electronics, electric vehicles, stationary energy storage, etc.), specific requirements in different applications, battery modules and packs, thermal management, battery management system, Aging/degradation of batteries, thermal runaway, safety issues, Equivalent-circuit modeling, physics-based modeling, transport phenomena in Li-ion batteries, recycling of Li-ion batteries.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-545 **Course Title:** Hydrogen Energy

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course outlines:** Introduction to Hydrogen Energy, Hydrogen Production, Hydrogen Separation, Purification, and Storage, Hydrogen-fuelled Transportation, Hydrogen Safety, Applications and Perspectives of Hydrogen.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-546 **Course Title:** Advance Design for Pressurized Vessel

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course outlines:** Advance design of thin and thick high pressure cylindrical and spherical shells under internal and external pressure; Construction of monoblock and multilayer vessels, design of flanges under high pressure, design of tall tower under severe conditions.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-547 **Course Title:** An Introduction to Rheology

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course outlines:** Review of Newtonian fluid mechanics: Conservation of mass and momentum equations, Newtonian constitutive relation, Flow problems; Standard flows of rheology and material functions: shear flows, elongational flows and associated material functions; Generalized Newtonian fluids with no memory and flow problems; Materials with memory effects (Generalized linear viscoelastic fluids): models and associated flow problems; Rheometry: different types of rheometers, associated rheological measurements and analysis of experimental data, Rheology of emerging smart materials: field (e.g. electric/magnetic field) or stimuli responsive materials, biomaterials etc.

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-548 **Course Title:** Introduction to Quantum Computing

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course outlines:** Traditional versus quantum computing, the fundamental definitions of quantum logic and computing, quantum comparator, linear algebra, single and multiple quantum bits, quantum programming, entanglement, protocols, and algorithms, error corrections, compilers, tools, and the relevant case studies.

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE/SCHOOL:** Department of Chemical Engineering

**Subject Code:** CHL-549 **Course Title:** Chemical Process Engineering

**L-T-P:** 3-1-0 **Credits:** 4 **Subject Area:** PEC

**Course outlines:** A brief history and structure of the chemical industry, raw materials and energy, base chemicals, global trends in the chemical industry, processes in oil refinery an overview; production of synthesis gas, bulk chemicals and synthetic fuels derived from synthesis gas, production of light alkanes, polymers, nylon 66, and acrylonitrile, inorganic bulk chemicals, sulphuric acid, nitric acid, chlorine, phosphoric acid, soap and detergent, paper and pulp; cement industry, cement production, types of cement and their applications, environmental impacts and sustainability in cement industry, air emissions ($CO_2$, $NO_X$, $SO_X$) and their mitigation, waste management and recycling in cement production, fertilizer industry, overview of nitrogenous, phosphatic, and potassic fertilizers, manufacture and properties of fertilizers, fates of fertilizer in soils, method of fertilizer applications, life cycle assessment (lca), process integration, process development.