# NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL




## Honors in
## THERMAL ENGINEERING

## SCHEME OF INSTRUCTION AND SYLLABI

## for B.Tech. Program

**(Effective from 2021-22)**

## DEPARTMENT OF MECHANICAL ENGINEERING

# Scheme of Instruction
# Honors in Thermal Engineering

| S.No | Subject name | Semester |
|---|---|---|
| 1 | ME5102 Computational Methods in Thermal Engineering | Odd |
| 2 | ME5513 Alternate Fuels and Emissions | Odd |
| 3 | ME5166 Design of Heat Transfer Equipment | Even |
| 4 | ME5164 Conduction and Radiation Heat Transfer | Even |
| 5 | ME5551 Automotive Electronics | Even |
| 6 | ME5161 Heating, Ventilation and Air-Conditioning (HVAC) | Even |

| Course Code: ME5102 | COMPUTATIONAL METHODS IN THERMAL ENGINEERING | Credits 3-0-0: 3 |
|---|---|---|

Prerequisites: Fluid Mechanics, Heat Transfer

Course Outcomes:

| | |
|---|---|
| **CO1** | Outline the steps involved in solving a fluid dynamics problem using computational methods |
| **CO2** | Derive the governing equations and understand the behaviour of the equations |
| **CO3** | Analyze the consistency, stability and convergence of various discretization Schemes for parabolic, elliptic and hyperbolic partial differential equations. |
| **CO4** | Analyze variations of SIMPLE schemes for incompressible flows and variations of Flux Splitting algorithms for compressible flows. |
| **CO5** | Select methods of grid generation techniques and application of finite difference and finite volume methods to thermal problems. |

Syllabus:

**Introduction:** Revision of Fluid Mechanics and Heat transfer, Derivation of Conservation equations of Mass, momentum and energy.

**Governing equations of fluid dynamics:** The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

**Finite volume method for 1-D, 2-D and 3-D steady state diffusion problems:** Finite volume method for Steady 1-D convection-diffusion problems, Conservativeness, Boundedness and Transportiveness, Central, Upwind, Hybrid and Power law schemes, QUICK and TVD schemes.

**Pressure Velocity Coupling in steady flows:** Staggered grid, SIMPLE algorithm, Assembly of a complete method, SIMPLER, SIMPLEC and PISO algorithms, Worked examples of the above algorithms.

**Finite volume method for 1-D unsteady heat conduction:** Explicit, Crank-Nicolson and fully implicit schemes, Transient problems with QUICK, SIMPLE schemes, Implementation of boundary conditions: Inlet, Outlet, and Wall boundary conditions, Pressure boundary condition, Cyclic or Symmetric boundary condition.

**Errors and uncertainty in CFD modelling:** Numerical errors, Input uncertainty, Physical model uncertainty, Verification and validation, Guidelines for best practices in CFD, Reporting and documentation of CFD results.

**CFD modelling of turbulent flows:** Characteristics of turbulence, Effect of turbulent fluctuations on mean flow, Turbulent flow calculations, Turbulence modelling, Large Eddy Simulation, Direct Numerical Simulation.

**Grid Generation:** Unstructured grid generation, Domain nodalization, Domain triangulation, Advancing front methods, The Delaunay method, The respective algorithms with examples.

**CFD for radiation heat transfer:** Governing equations for radiation heat transfer, Popular radiation calculation techniques using CFD, The Monte Carlo method, The discrete transfer method, Raytracing, The discrete ordinates method.

## Learning Resources:

### Text Books:

1. An introduction to computational fluid dynamics: the finite volume method, H.K. Versteeg, W. Malalasekera, , Longman Group, England, 1996
2. Computational Fluid Dynamics, Anderson, J.D(Jr), McGraw-Hill Book Company, 2017.

### Reference Books:

1. Computational Fluid Dynamics, Vol. I, II and III, Hoffman, K.A., and Chiang, S.T., , Engineering Education System, Kansas, USA, 2000.
2. Computational Fluid Dynamics, T.J. Chung, Cambridge University Press, 2014, 2nd Edition
3. Computational Fluid Mechanics and Heat Transfer, D.A. Anderson, J.C. Tannehill, and R.H. Pletcher, CRC Press, 2013, 3rd Edition,

### Online Resources:

1. Computational Fluid Dynamics using Finite Volume Method by Dr. Kameswararao Anupindi (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106294/)
2. Foundations of Computational Fluid Dynamics by Prof. S. Vengadesan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106186/)
3. Computational Fluid Dynamics by Prof. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105045/

| Course Code: ME5166 | DESIGN OF HEAT TRANSFER EQUIPMENT | Credits 3-0-0:3 |
|---|---|---|

Prerequisites: Heat Transfer

Course Outcomes:

| | |
|---|---|
| **CO1** | Understand the physics and the mathematical treatment of typical heat exchangers. |
| **CO2** | Apply LMTD and Effectiveness - NTU methods in the design of heat exchangers |
| **CO3** | Design the shell and tube heat exchanger. |
| **CO4** | Apply the principles of boiling and condensation in the design of boilers and condensers |
| **CO5** | Design cooling towers from the principles of psychrometry |

Syllabus:

**Introduction to Heat Exchangers:** Definition, Applications, Various methods of classification of heat exchangers with examples.

**Governing Equation for heat exchangers:** Derivation from steady-state steady-flow considerations.

**Mathematical treatment of Heat Exchangers:** Concept of Overall Heat Transfer Coefficient, Derivation of the concerned equations, Fouling, Fouling Factor, Factors contributing to fouling of a heat exchanger, Ill-Effects of fouling, Numerical Problems.

**Concept of Logarithmic Mean Temperature Difference:** Expression for single-pass parallel-flow and single-pass counter flow heat exchangers – Derivation from first principles, Special Cases, LMTD for a single-pass cross-flow heat exchanger – Nusselt's approach, Chart solutions of Bowman et al. pertaining to LMTD analysis for various kinds of heat exchangers, Numerical Problems, Arithmetic Mean Temperature Difference [AMTD], Relation between AMTD and LMTD, Logical Contrast between AMTD and LMTD, LMTD of a single-pass heat exchanger with linearly varying overall heat transfer coefficient [U] along the length of the heat exchanger.

**Concept of Effectiveness:** Effectiveness-Number of Transfer Units Approach, Effectiveness of single-pass parallel-flow and counter-flow heat exchangers, Physical significance of NTU, Heat capacity ratio, Different special cases of the above approach, Chart solutions of Kays and London pertaining to Effectiveness-NTU approach, Numerical Problems.

**Hair-Pin Heat Exchangers:** Introduction to Counter-flow Double-pipe or Hair-Pin heat exchangers, Industrial versions of the same, Film coefficients in tubes and annuli, Pressure drop, Augmentation of performance of hair-pin heat exchangers, Series and Series-Parallel arrangements of hair-pin heat exchangers, Comprehensive Design Algorithm for hair-pin heat exchangers, Numerical Problems.

**Shell and Tube Heat Exchangers:** Single-Pass, One shell-Two tube [1S-2T] and other heat exchangers, Industrial versions of the same, Classification and Nomenclature, Baffle

arrangement, Types of Baffles, Tube arrangement, Types of tube pitch lay-outs, Shell and Tube side film coefficients, Pressure drop calculations, Numerical Problems.

**Principles of Boilers and Condensers:** Boiling, Fundamentals and Types of boiling – Pool boiling curve, Various empirical relations pertaining to boiling, Numerical problems on the above, Condensation – Classification and Contrast, Types of condensers, Nusselt's theory on laminar film-wise condensation, Empirical Refinements, Several empirical formulae, Numerical problems.

**Cooling Towers:** Cooling towers – basic principle of evaporative cooling, Psychrometry, fundamentals, Psychrometric chart, Psychrometric Processes, Classification of cooling towers, Numerical problems.

LeaLearning Resources:

Text Books:

- Compact Heat Exchangers, Kays, W. M. and London, A. L., McGraw – Hill, New York, 2nd Edition.
- Process Heat Transfer, Donald Q. Kern, McGraw – Hill, New York.

Reference Books:

- Fundamentals of Heat and Mass Transfer, Incropera, F. P. and Dewitt, D. P., 4th Edition, John Wiley and Sons, New York.
- Fundamentals of Heat Exchanger Design, Shah, R. K. and Sekulic, D. P., John Wiley and Sons, New Jersey.

| Course Code: ME5513 | ALTERNATE FUELS AND EMISSIONS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisites: NIL

Course Outcomes:

| | |
|---|---|
| **CO1** | Understand the need of alternate fuels for IC engines |
| **CO2** | Evaluate the performance of the engine with alternate fuels and blends with petroleum derived fuels. |
| **CO3** | Examine the viable production and storage methods of alternate fuels. |
| **CO4** | Measure the pollutant emissions from IC Engines as per standards and describe emission control methods. |

Syllabus:

**Introduction**: Present energy scenario (worldwide and India)- Statistics of petroleum fuels- of liquid and gaseous fuels in Automobiles-Problems with highly exploited petroleum derived fuels-Desirable properties of a good alternate fuel – Availability and properties of alternate fuels, ASTM standards.

**Alcohols**: General Use of Alcohols – Thermo-combustion properties as Engine fuel – Gasolene and alcohol blends – Production methods of widely used alcohols-Performance in SI and CI Engines – Methanol and ethanol and Gasolene/diesel blends – Combustion Characteristics in engine – emission characteristics-Modification required to operate with alcohols and its blends with petrol and diesel-brief details of flexi fuel engines(FFE)-use of higher alcohols.

**Natural Gas, LPG**: Use of natural gas as CNG and LNG-Availability of CNG and LNG-, properties, modification required to use in engines – performance and emission characteristics of CNG using LPG in SI & CI engines.-Production and storage of CNG/LNG.

**Bio-gas:** Production methods of bio-gas, properties of bio-gas as a fuel, performance and emission characteristics of engine with bio-gas and its blends with petrol/diesel-brief information on compressed gio-gas and its storage.

**Vegetable oils**: Characteristics of vegetable oils as alternate fuel- edible and non-edible vegetable oils-conversion of vegetable oils into diesel like fuel(biodiesel) -esterification, blending and micro-emulsions-Performance and emission characteristics of engines with biodiesel and blends-B20.

**Hydrogen :**Suitable characteristics of hydrogen fuel- hydrogen production methods- storage of hydrogen-use of hydrogen as fuel in engines -Hydrogen in fuel cells.

**Engine Emissions :** Harmful effects of engine-out emissions-Mechanism of formation of pollutant emissions such as carbon monoxide, unburned hydrocarbons, oxides of hydrogen and aldehydes.

**Emission measurement and control methods:** Measurement of pollutants using flame ionization detection, NDIR, chemiluminescent analyzer and particulate matter(soot/smoke)-Emission norms-EURO and Bharat stage Engine emission control methods-in cylinder and after treatment methods.

## Learning Resources:

### Text Books:

1. Alternative Transportation Fuels: Utilisation in Combustion Engines, M.K. Gajendra Babu , K.A. Subramanian CRC Press ,2013
2. Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines,Akhilendra Pratap Singh, Yogesh C. Sharma,Nirendra N. Mustafi ,Avinash Kumar Agarwal, Springer 2020.

### Reference Books:

1. Engine Emissions: Pollutant formation and advances in control Technology, Norbe Pundir B.P, Narosa Publishing House,2013.
2. Alternative Fuels for Transportation, Ramadhas, A S,CRC Press 2012.

### Online Resources:

1. https://nptel.ac.in/courses/112/104/112104033/Engine Emissions-B.P.Pundir

| Course Code: ME5164 | CONDUCTION AND RADIATION HEAT TRANSFER | Credits 3-0-0: 3 |
|---|---|---|

Prerequisites: NIL

Course Outcomes:

| | |
|---|---|
| **CO1** | Understand the fundamental principles of convection heat and mass transfer |
| **CO2** | Formulate and solve convective heat transfer problems for internal and external flows |
| **CO3** | Analyze turbulent boundary layer flow problems |
| **CO4** | Apply the principles of mass transfer to solve complex problems |
| **CO5** | Understand the principles of convection in porous media |

Syllabus:

**Introduction:** Course structure, Basics of Thermodynamics, Fluid mechanics and Heat transfer.

**Fundamental Principles:** Continuity, momentum and energy equations, Reynolds transport theorem, Second law of TD, Rules of Scale analysis, Concept of Heat line visualization.

**Laminar forced convection**: **External flows:** Boundary layer concept, velocity and thermal boundary layer, Governing equations, Similarity solutions, various wall heating conditions, Flow over sphere, wedge and stagnation flow.

**Laminar forced convection: Internal flows:** Fully developed laminar flow: Constant heat flux, Constant wall temperature, developing length.

**External Natural convection:** Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Boundary layer equations, Scale analysis, Low and high Prandtl number fluids, vertical walls, horizontal walls, sphere.

**Internal Natural Convection:** Natural convection in enclosures: isothermal and constant heat flux. Sidewalls, triangular enclosures, heated from below, inclined enclosures, annular space between horizontal cylinders.

**Turbulent boundary layer flow:** Boundary layer equations, mixing length model, flow over single cylinder, crossflow over array of cylinders, Natural convection along vertical walls, turbulent duct flow.

**Mass transfer:** Formulation of the Mass Transfer Problem using different Models, Application of Reynolds Flow Model to different problems involving simultaneous heat/mass transfer.

**Convection in porous media:** Basics of porous media, flow models (Darcy, Brinkmann, Forchheimer and Generalized non-Darcy model).

Learning Resources:

Text Books:

1. Convection Heat Transfer, Bejan, A., John Willey and Sons, New York, 2001.
2. Convective Heat and Mass Transfer, Ghiaasiaan, S.M., Cambridge, 2015.

## Reference Books:

1. Fundamentals of Heat and Mass Transfer, Incropera, F. P. and De Witt, D. P., John Wiley and Sons, New York, 2006, 5th Edition.
2. Convective Heat and Mass Transfer, Kays, W. M. and Crawford, M. E., Tata McGraw Hill, 2017, 4th Edition.
3. Convective Heat Transfer, Louis, C. Burmeister, John Willey and Sons, New York, 2003.

## Online Resources:

1. Convective Heat Transfer by Prof. Ajit K. Kolar (IIT Madras) and Dr. Arvind Pattamatta (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106170/)
2. NOC:Convective Heat Transfer by Prof. Saptarshi Basu (IISc Bangalore), NPTEL Course (Link: https://nptel.ac.in/courses/112/108/112108246/)
3. Convective Heat and Mass Transfer by Dr. Amaresh Dalal (IIT Guwahati), Prof. Gautam Biswas (IIT Kanpur) and Prof. Vijay K Dhir (UCLA), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104159/)

| Course Code: ME5551 | AUTOMOTIVE ELECTRONICS | Credits 3-0-0: 3 |
|---|---|---|

Prerequisites: NIL

Course Outcomes:

| | |
|---|---|
| **CO1** | Understand the electronic circuit fundamentals, safety and basic test equipment. |
| **CO2** | Analyze vehicle electronic circuits. |
| **CO3** | Outline the working of batteries, starting systems, charging systems, ignition systems and auxiliaries. |
| **CO4** | Analyze the performance of sensors and ECU. |

Syllabus:

**Introduction:** Overview of the course, Examination and Evaluation patterns, History of Automotive electronics. Circuit fundamentals**:** voltage, current**,** resistance, circuits components, series and parallel circuits in vehicles, basic test equipment: voltmeters, ammeters, ohmmeter, Digital Storage Oscilloscope

**Electronic fundamentals:** Basic principles of semiconductor technology, electronic control input devices, Passive components, Semiconductor components, Manufacture of semiconductor components and circuits

**Wiring diagrams and Batteries:** wiring diagram symbols, using the wiring diagram, automotive batteries, diagnosing batteries, servicing batteries.

**Electrical and electronic systems in the vehicle:**. Motronic-engine management system, Electronic diesel control (EDC), Lighting technology, defogger, horn, and windshield wiper circuits, diagnosing defogger, horn, and windshield wiper circuits, motor driven accessories, diagnosing motor driven accessories, Electronic stability program (ESP), Adaptive cruise control (ACC), Occupant-protection systems, Safe working practices - Work cloths, eye protection, fire protection, battery safety.

**Starting and charging systems:** starting circuits, solenoid shift starters, diagnosing and servicing solenoid shift starters systems, positive engagement starters, diagnosing and servicing positive engagement starting system, gear-reduction starters, diagnosing gear-reduction starters, charging system overview, field circuits, diagnosing and servicing the charging system.

**Ignition systems and accessories:** Primary and Secondary ignition systems, diagnosing and servicing distributed primary and secondary ignition systems, diagnosing and servicing the secondary ignition system on a distributor-less vehicles, distributor-less ignition primary circuits, diagnosing and servicing the primary circuit on a distributor-less ignition system.

**Electronic control units and sensors:** Vehicle sensors-speed, Hall phase sensors, temperature sensor, fuel level, battery condition, emissions, feedback circuits, Micromechanical yaw-rate sensors, Accelerator-pedal sensors, Position sensors for transmission control Steering-angle sensors, Axle sensors.

**Cooling of Electronics Equipment:** Cooling load of electronics equipment, thermal

environment, Electronics cooling in automotive systems, air cooling, liquid cooling, immersion cooling.

## Learning Resources:

### Text Books:

1. Automotive Technology, Electricity and Electronics, Al Santini, Cengage Publishers,2011.
2. Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive, Robert Bosch GmbH, 5th edition, John Wiley & Sons. Inc. and Bentley Publishers, 2007

### Reference Books:

1. Understanding Automotive Electronics, William Ribbens, 6th Edition, Elsevier, 2011.

### Online Resources:

1. https://www.elprocus.com/

| Course Code: ME5161 | HEATING, VENTILATION AND AIR-CONDITIONING (HVAC) | Credits 3-0-0: 3 |
|---|---|---|

Prerequisites: NIL

Course Outcomes:

| | |
|---|---|
| **CO1** | Understand the fundamentals of Psychrometry |
| **CO2** | Apply human comfort indices and comfort charts to design indoor conditions of HVAC systems. |
| **CO3** | Estimate heating and cooling loads for buildings according to ASHRAE procedures and standards. |
| **CO4** | Design and evaluate a complete air distribution system including fan, duct, and installation requirements for a typical HVAC system. |

Syllabus:

**Introduction**: brief history of air conditioning and impact of air conditioning. HVAC systems and classifications, Heat Pumps

**Psychrometry of Air Conditioning Processes:** Thermodynamic properties of moist air, Important Psychrometry properties, Psychrometric chart; Psychrometric process in air conditioning equipment, applied Psychrometry, air conditioning processes, air washers.

**Comfort Air Conditioning:** Thermodynamics of human body, metabolic rate, energy balance and models, thermoregulatory mechanism. Comfort & Comfort chart, Effective temperature, Factors governing optimum effective temperature, Design consideration. Selection of outside and inside design conditions.

**Heat Transfer Through Building Structures:** Solar radiation; basic concepts, sun-earth relationship, different angles, measurement of solar load, Periodic heat transfer through walls and roofs. Empirical methods to calculate heat transfer through walls and roofs using decrement factor and time lag method. Infiltration, stack effect, wind effect. CLTD/ETD method – Use of tables, Numerical and other methods, Heat transfer through fenestration – Governing equations, SHGF/SC/CLF Tables

**Load Calculation**: Types of air-conditioning systems, General consideration, internal heat gains, system heat gain, cooling and heating load estimate.

**Ventilation System:** Introduction- Fundamentals of good indoor air quality, need for building ventilation, Types of ventilation system, Air Inlet system. Filters heating & cooling equipment, Fans, Duct design, Grills, Diffusers for distribution of air in the workplace

Learning Resources:

Text Books:

1. Principles of Refrigeration, Gosney W.B., Cambridge University Press, 1982.
2. Thermal Environmental Engineering, Threlkeld J.L., Prentice Hall, New Jersey 1962.

Reference Books:

1. Principles of Refrigeration, Dossat, R.J. and Horan, T.J., Prentice Hall, 2001, 5th Edition.
2. Refrigeration & Air conditioning, Arora, R.C., PHI, 2010

## Online Resources:

1. Refrigeration and Air-Conditioning by Prof. M Ramgopal (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105129/)
2. NOC:RAC Product Design by Prof. Sanjeev Jain (IIT Delhi) and Prof. Bhupinder Godara (IIT Delhi), NPTEL Course (Link: https://nptel.ac.in/courses/112/102/112102248/)