Master Degree in Energy & Renewable Energy Engineering

Course Syllabus

**Master Program in Energy & Renewable Energy Engineering**

| First Course | | | | Second Course | | |
|---|---|---|---|---|---|---|
| **Program** | **hours/ Week** | **Units** | | **Program** | **Hours/ Week** | **Units** |
| Renewable energy Systems I | **2** | **2** | | Renewable energy Systems II | **2** | **2** |
| Advanced Thermodynamics | **2** | **2** | | Turbo-Machinery & Power Plants | **2** | **2** |
| Advanced Heat Transfer | **2** | **2** | | Modeling, Simulation & Control for Energy Sys. | **2** | **2** |
| Advanced Engineering Mathematics and Numerical Analysis | **3** | **3** | | Energy Storage Systems | **2** | **2** |
| Energy and Environment | **2** | **2** | | Advanced Fluid Mechanics and CFD | **3** | **3** |
| English Language I | **1** | **1** | | English Language II | **1** | **1** |
| | | | | Research Methodology | **2** | **2** |
| **Total** | **12** | **12** | | **Total** | **14** | **14** |

# *First Course*

## Renewable Energy Systems I

### (1) Solar Energy

**1)** Incidence solar radiation concept (The Solar Angles; The Sun Position; Sun-Path Diagrams; Solar Time Solar radiation on horizontal & inclined (tilted) plane.
**2)** Solar Collectors: Flat plate collectors (FPC); Parabolic trough collector (PTC); Tubular solar energy collectors
**3)** Solar tracking systems.
**4)** Application of solar heat.
**5)** Solar thermal power plants.
**6)** Photovoltaic Cell (Photovoltaic applications; Modeling of solar irradiance and cells; Optimized using of PV arrays; Hybrid Photovoltaic systems).

**REFERENCES:**

[1] Ted J. Jansen "Solar Engineering Technology", (1985).
[2] D. Yogi Goswami "Principle of Solar Engineering", (2015).
[3] John A. Duffie "Solar Engineering of Thermal Processes, Photovoltaic and Wind", (2020).
[4] Saurabh Kumar Rajput "Solar Energy Fundamentals, Economic and Energy Analysis", (2017).
[5] Djamila Rekioua, Ernest Matagne "Optimization of Photovoltaic Power systems, Modelization ,Simulation and Control", (2012).

### (2) Wind and hydro power plant

**1)** Wind turbine concept & Characteristics
**2)** One-Dimensional Wind Turbine Model: Aerodynamics of Wind Turbines
**3)** Wind Turbine Average Power and Energy Production
**4)** Modeling and control of wind turbine.

5) Introduction to hydroelectric power plant
6) Calculation of extracted hydro power energy
7) Characteristic of Kaplan turbine and Frances's turbine.
8) Hydroelectric control system.

## Advanced Thermodynamics

1) Equation of state, thermodynamics relations, Relationships between specific heats.
2) Second law of thermodynamics (Exergy), Principle of heat engine and heat pumps.
3) Combustion (Introductions, air to fuel ratio, enthalpy of formation, enthalpy of combustion, adiabatic flame temperature, actual combustion analysis, constant of equilibrium).
4) Equilibrium of thermodynamic systems.
5) Thermodynamic properties of system with constant chemical composition.
6) Law of corresponding states general thermodynamic relations.
7) The Clausus clapeyron equation, Liquidification of gases.
8) Thermodynamic properties of ideal gases and gas mixtures of constant composition.
9) Thermodynamic properties of gas mixtures with variable composition.
10) Available and unavailable energy, applications of thermodynamic to special systems.
11) Introduction to statistical thermodynamics.

**References**

[1] Thermodynamics: an Engineering Approach / Yunus Cengle.
[2] Fundamental of Classical Thermodynamics / Van Wylen.

## Advanced Heat transfer

1) Conduction heat transfer: three dimensional Fourier conduction equation, unidirectional heat conduction with heat dissipation to the environment, analytical and numerical solutions of one, two, three- dimensional unsteady-state heat conduction, insulation, critical thickness of insulation, fins, transient heat transfer ,low temperature insulation, thermal boundary layer theory.
2) Convection heat transfer: forced convection in laminar flow, forced convection in turbulent flow, natural convection from horizontal surface, natural convection from vertical surface and tubes.
3) Condensation and boiling: theory of laminar film condensation, bubble growth and collapse.
4) Radiation heat transfer: radiant heat exchanges between black and gray bodies, radiation between hot and its enclosure, radiation from gases, flames and solar radiation.
5) Multiphase heat transfer
6) Heat transfer in porous media
7) Heat exchangers. (heat recovery systems, ……)
8) Mass transfer: steady state diffusion of gases and liquids through solids, equi-molar diffusion, mass transfer coefficient, similarity relations, simultaneous heat and mass transfer.

## Advanced Engineering Mathematics and Numerical Analysis

1) Linear Algebra, Vector calculus, Ordinary Differential Equations, Laplace Transform, Fourier analysis and Partial Differential Equations.
2) Complex analysis, Power series, Taylor and Laurent theory, Optimization.
3) Sturm Louville Problem, Tensors, Functions of complex variables.
4) Advanced calculus (Introductory real analysis), probabilities and statistics.
5) Partial differential equation.
6) Fourier integrals (transformation).
7) Special functions (Legendre and Bessel function, Alpha and Beta function, Error functions, ….etc).
8) Numerical solution of ordinary differential equations: single step formula, Taylor's formula, Runge-Kutta methods, Euler's (modified and improved) methods, error propagation, Simultaneous ordinary differential equation.
9) Numerical integration: open integration formulas, closed integration formulas, truncation error, stability, and step wise control.
10) Approximation and the solution of partial differential equations: using finite difference methods, explicit method, implicit method, convergence , stability, consistency , Crank-Nicolson method applications.
11) Boundary value problem
12) Numerical solution of the system of equations: a)linear system, Gaussian elimination, Jacobi iteration method, Gauuss-Sedial method successive relaxation over and under relaxation
b)non-linear equation, fixed point method, Newton-Raphson method.
13) Least square approximation
14) Finite elements method, finite volume approach
15) Interpolation, improvement of convergence, and sensitivity of results and parameter estimation

## Energy and Environment

1) Steady state system with neoconservative pollutants: Batch system, step function response
2) Mathematics of growth: Disaggregated growth rate, economic resource production rate, population growth, maximum sustainable yield.
3) Risk assessment: Hazard index for no carcinogenic effects, human exposure assessment, contaminant degradation, risk characterization.
4) Contaminant transport: Dispersion and diffusion, control of ground water, contaminant in ground water, ground water remediation technology
5) Water treatment: Membrane process, membrane bioreactor, waste water treatment, , sludge treatment, nutrient removal, hazardous waste, hazardous waste treatment technologies, waste incineration

6) Atmospheric stability and mixing depth: Air quality and emissions standard, controlling emissions and improving air quality, particulate matter and control, automobile emission control, alternative fuel, wind speed, indoor air quality
7) Global atmospheric change: Global temperature, the greenhouse effect, the carbon cycle, ozone global warming potential, stabilizing greenhouse gases, waste management, energy and greenhouse gases.

## English Language I

1) Reading: filling in forms and extensive reading
   - Writing: Error correction, punctuation, and spelling in addition to writing an informal email.
2) Skimming and scanning: reading for the general idea, and particular information
   - Brainstorming ideas: topic areas and examples; completing a paragraph
   - Linking ideas: but, however, although
   - Writing a description of my country
3) Reading: An Unexpected Journey
   - Predicting content: using the title and the pictures
   - Meaning from context: guessing the meaning of new words
   - Mistaken identity
   - Varying the structure: Making writing interesting
   - Writing an article
4) Identifying the main message: using topic sentences to identify paragraph
   - Organizing ideas (1): planning the arguments for and against
   - Linking ideas (2): first, for instance, in conclusion…
   - Writing a discursive essay
5) Purpose and audience: using visual and written clues
   - Using formal expressions: writing academic emails and letters
   - Writing a formal email

**Reference :**

Liz and John Soars, **Headway Academic Skill: Reading, Writing, and Study Skills**
*Level 2 Student's book*

## *Second Course*

### Renewable Energy System II

### (1) Hydrogen and Fuel Cell Technology

1) Hydrogen Economy
2) Review of Fuel Cell Types and Configuration of Individual Cell, Stack and Fuel Cell System
3) Thermodynamics of Fuel Cells
4) Fuel Cell Reaction Kinetics
5) Fuel Cell Charge Transport.
6) Heat and Mass Transfer in Polymer Electrolyte Fuel Cells
7) Fuel Cell characterization and Modeling
8) Fuel cell system design, optimization and economics
9) Challenges of Fuel Cell Commercialization
10) Application of nanostructured materials in fuel cells
11) Micro Fuel Cells

**References**

1. "Fuel Cell Engines", Matthew M. Mench, 2008 by John Wiley & Sons, Inc.
2. "Fuel Cell Fundamentals", O'Hayre, Cha, Colella, and Prinz, 2016 by John Wiley & Sons.

### (2) Energy from biomass and waste

1. Review of biomass resources, Routes of Biomass Conversion Processes and biofuels production technologies, and Characteristics of Biomass Fuels: Composition, Ultimate and Proximate Analyses, and Heating Value
2. Thermochemical Conversion (Pyrolysis, Gasification, and combustion)
   - **a)** Pyrolysis: Torre-faction, Slow and Fast Pyrolysis, Charcoal Production.
   - **b)** Gasification: Fundamentals, Fixed bed Gasifiers, Technical and operations; problems with Fixed bed Gasifiers, Fluidized bed Gasifiers, Entrained Bed Gasifiers, Comparison between Fixed bed and Fluidized bed Gasifiers, Gas Treatment, Equilibrium and Kinetic Considerations.
   - **c)** Combustion: Fundamentals, Furnaces, Fixed bed systems, Fluidized bed systems, Emission reduction, Steam cycle, Residential and small commercial systems, Solid waste incineration, Electric power production, operating problems
3. Microbial Growth
4. Biochemical Conversion
   - **a)** Biogas Production: Types of Substrates, Digester Design, Operational Problems, Kinetic Considerations.

**b)** Ethanol Production: Basic Production Processes from Sugar Biomass, Starch Biomass, lignocellulose materials, Distillation

**c)** Methanol Conversion Technologies: Methanol properties, Methanol Production from biomass

**d)** Biodiesel Conversion Technologies: Properties (vegetable oil, biodiesel, diesel), Biodiesel Production from vegetable oil, and biomass

5. Wastewater treatment and energy recovery.

## Turbo-Machine and Power Plants

**1)** Compressible fluid flow. (Introduction, Wave propagation in compressible flow, Isentropic flow Through convergent divergent nozzle, Normal shock, Oblique shock wave).
**2)** Turbo machine theory.
**3)** Turbine performance analysis. (under design point-DP, off design point- OD)
**4)** Steam turbine control systems.
**5)** Power plant energy & Exergy analysis (cogeneration, regeneration, combined gas steam power plant).
**6)** Homologous units, specific speed: elementary cascade theory, theory of turbo machines.

**References:**

[1] Steam turbine theory and practice, by W. J. Kearton.
[2] Combined-Cycle Gas & Steam Turbine Power Plants, by Rolf Kehlhofer 2009
[3] Applied Thermodynamics: Availability Method And Energy Conversion, By KamW. Li, 1995
[4] Turbomachinary performance analysis by R I Lewis., 1996

## Modeling, simulation and control for Energy System

**1)** Micro controller simulation for energy system.
**2)** Analyze and design the most suitable approaches for any modeling task.
**3)** Formulation elements of the model
**4)** Verification of the model
**5)** Time-Domain Dynamics and Control
**6)** Analysis of Multivariable Systems
**7)** Computer simulation
**8)** Multivariable process controller
**9)** Stability analysis

## Energy Storage Systems

**1)** Cycling and performance characteristics of super capacitor, hybrid super capacitor and batteries Charging and discharging processes, importance of Ragone plot, Type of anode and cathode, energy density evaluation, effect of shape of electrode, performance criteria
**2)** Energy storage in multiphase regime

Phase equilibrium of pure system and mixtures, rule phases, utectic, peritectics and azeotropic systems(gas-liquid), thermal storage, Storing of energy in porous material, Field of application, estimation the porosity, application of Darcy law, solar energy storing, type of porous material in energy storage field

**3)** Unsteady calculations of energy storage
Field of applications, balance of energy around selected system, effect of properties on the stability of performance, increase efficiency via reduction of losses, determination of thermal efficiency, hydropower plant

**4)** Selection of electrodes for best energy storage
Highlight the measured property, performance of material and availability and effect of shape , fabrication of materials , testing of performance; thermal or potential and current…

**5)** Multidimensional energy storage
Type of direction of transport, buoyancy effect in transport, diffusion of thermal effect in three dimensions

**6)** Energy storage in buildings and other applications
Design of building to meet energy conservation, use of sustainable energy in design, role of pcm to store energy in walls, roofing …etc. elevation of building and its effect on energy distribution and storing

**7)** Mechanical storage
Compressed air as energy storage, method of increasing efficiency and usage of CAES, thermodynamic considerations, feasibility of application in Iraq, hydropower plant design

**References**

[1] M Sterner, I Stadler. “Handbook of energy storage: Demand, technologies, integration" Springer, (2019).
[2] A Rufer. “Energy storage: systems and components“ Taylor & Francis, (2017)
[3] AG Ter-Gazarian. “Energy storage for power systems” Peter Peregrinus, (1994)

## Advanced Fluid Mechanics and CFD

1. Review of undergraduate fluid mechanics - Fluid properties, fluid kinematics, forces in fluids, Bernoulli equation, conservation laws
2. Control volume analysis - Application of conservation laws to fixed and deforming, inertial and non-inertial global control volumes
3. Governing equations of fluid motion - Derivation of Navier-Stokes and continuity equations, Eulerian and Lagrangian viewpoints, analytical solutions for viscous flows, lubrication approximation, vorticity theorems
4. Inviscid fluid flow - Irrotational flow, potential flow solutions, numerical solution of Laplace equation, Bernoulli equation normal to a streamline
5. Boundary layer theory - Boundary layer equations, similarity solutions, momentum integral formulation, * numerical solutions
6. Stability, transition, and turbulence - Linear stability theory for laminar shear flows, Rayleigh and Orr-Sommerfeld equations, characteristics of transitioning and turbulent flows

7. Fluid flow in porous media.
8. Multiphase flow.
9. Micro/nanofluidics - Surface tension, creeping flow electrokinetic phenomena,* slip flow, Knudsen number, free molecular flow, molecular dynamics simulation,* Boltzmann transport equation*
10. Introduction to computational fluid dynamics - Finite volume methods, convection schemes, turbulence models*

* These sections will be covered if time permits.

**References**

[1] Fluid Mechanics (6th edition). P. K. Kundu, I. M. Cohen, D. R. Dowling. Academic Press, 2015.
[2] Viscous Fluid Flow (3rd edition). F. M. White. McGraw-Hill, 2005.
[3] T.J. Chung, Computational fluid dynamics, Cambridge University Press, Cambridge, United Kingdom, 2002.

## English Language II

**1)** Making notes: organizing, recording, and remembering important information.
- Interpreting meaning: recognizing fact and speculation
- Paraphrasing and summarizing: using other sources
- Writing a summary

**2)** Past and Present
- Using original sources**:** dealing with difficult language and unknown vocabulary
- Using the internet: search engines; online encyclopedia; subject directories
- Developing a search plan: making a search efficient and reliable

**3)** Rephrasing and explaining: dealing with difficult scientific and technology words
- Avoiding repetition: pronouns and what they refer to
- Linking ideas: cause and result
- Coherent writing: Writing up notes
- Writing from notes

**4)** Intensive reading: Strategies for focusing your reading
- Linking ideas: requesting words to describe a process
- The passive voice: writing in a neutral style
- Clarifying a sequence: describing a process

**5)** Interpreting data: Statistical information in graphs, charts, and texts
- varying vocabulary
- avoiding repetition: describing graphs using synonyms,
- adjectives + nouns+ ,verbs+ adverbs

**Reference :**

Liz and John Soars, Headway Academic Skill: Reading, Writing, and Study Skills
*Level 2 Student's book*

## Research Methodology

1) Understand basic concepts of research and its methodologies.
2) Identify appropriate research areas and avenues.
3) Select and define appropriate research problem and parameters.
4) Prepare a project proposal (to undertake a project).
5) Organize and conduct research in an scientific and ethical manner.
6) Selection of mathematical and analytical tools.
7) Write a research report and thesis.
8) Effectively communicate with the scientific society.
9) Understand the social responsibility as an engineer.

**References**

[1] Ranjit Kumar. "Research Methodology" Longman, 1996
[2] Lindsay D. “A Guide to Scientific Writing” Longman, 1995
[3] Ralph Berry. “How to write a Research Paper”, Pergamon, 1986
[4] Gerson S J and Gerson S M. “Technical Writing Process and Product”, Prentice Hall, 1992
[5] Coley S M and Scheinberg C A, "Proposal Writing", Newbury Sage Publications, 1990