MEC7230: Numerical Methods in Energy Engineering

Hours per Semester				Weighted Total Mark	Weighted Exam Mark	Weighted Continuous Assessment Mark	Credit Units
LH	PH	TH	CH	WTM	WEM	WCM	CU
40	0	10	45	100	60	40	3

Course Description

This course give an overview of the fundamentals of numerical methods used in engineering related to energy systems such as CFD (computational fluid dynamics), Heat transfer, and structural analysis. It gives a background on how to apply numerical methods in the design and testing of related equipment and other hardware. The main emphasis is on practical use of codes based on Finite Element/Volume methods for subsonic incompressible and compressible recirculating flows

Course Objectives

- To develop an understanding for: the major approaches and methodologies used in CFD, the interplay of physics and numerics, the methods and results of numerical analysis
- To help the student gain experience in the actual implementation of numerical methods in energy engineering
- To develop the student skills in: implementing and using basic CFD methods, computer use and programming and debugging

Learning Outcomes

At the end of the course students should be able to:

- Describe the physical significance of each term in the governing equations for CFD.
- Effectively use a commercial CFD package to solve practical CFD problems.
- Quantify and analyze the numerical error in solution of the CFD, PDE's.
- Formulate explicit and implicit algorithms for solving the Navier Stokes Equations
- Create and demonstrate verification strategies for evaluating CFD code.

Course content

1. Introduction to CFD **(3 Hours)**

- What is computational fluid dynamics?
- Principles of fluid mechanics
- Different ways of expressing the fluid-flow equations
- Basic principles of CFD
- The main discretisation methods

2. Fluid-flow equations **(6 Hours)**

- Control-volume approach
- Conservative flow equations – control-volume and differential forms
- Other differential forms of the fluid-flow equations
- Compressible and incompressible flow
- Non-dimensionalisation

3. Approximation and Simplified Equations **(5 Hours)**

- Steady-state *verses s* time-dependent
- Two-dimensional *verses* three-dimensional
- Incompressible *verses* compressible
- Inviscid *verses* viscous
- Hydrostatic *verses* non-hydrostatic
- Boussinesq approximation (buoyancy-affected flow)
- Depth-averaged / shallow-water equations
- Reynolds-averaged equations (turbulent flow)
- Potential flow

4. The Scalar Transport Equations **(6 Hours)**

- The generic scalar-transport equation
- Control-volume notation
- Discretising diffusion
- Discretising the source term
- Assembling the algebraic equations
- Discretisation properties
- Implementation of boundary conditions
- Solution of the algebraic equations

5. The Momentum Equations **(4 Hours)**

- Scalar-transport equations for momentum
- Pressure-velocity coupling
- Pressure-correction methods

6. Time Depended Methods **(5 Hours)**

- The time-dependent scalar transport equation
- One-step methods
- Multi-step methods
- Uses of time-marching in CFD

8. Turbulence Modelling **(6 Hours)**

- Review of turbulence
- Objectives in turbulence modelling
- Eddy-viscosity models
- Advanced turbulence models
- Wall boundary conditions

9. The CFD Process **(5 Hours)**

- Introduction
- The computational mesh
- Boundary conditions
- Flow visualisation

Mode of delivery

This course will be delivered through lectures, tutorials, exercises, field visits and group projects aimed at solving real life problems.

Method of Assessment

Students will be assessed through assignments, tests, practical work and projects which make up the course work and a final exam at the end of the course as follows:

Course work	40%
Final Exam	60%
Total Mark	100%

Reference textbooks

[1] H K Versteeg & W Malalasekera, 1995. An Introduction to Computational Fluid Dynamic (The Finite Volume Method), Longman Scientific & Technical, ISBN 0-582-21884

[2] Richard Hamming, 1987. Numerical Methods for Scientists and Engineers, Dover Publications 2nd Ed. ISBN-10: 9780486652412.

[3] John Anderson, 1995. Computational Fluid Dynamics, McGraw-Hill Science/Engineering/Math; 1st Ed, **ISBN-10:** 9780070016859.

[4] Richard Pletcher, John Tannehil, Dale Anderson (1997). Computational Fluid Mechanics and Heat Transfer, 2nd Ed. (Series in Computational and Physical Processes in Mechanics and Thermal Sciences) Taylor & Francis Publishers, ISBN-10: 9781560320463