Course Syllabus (Tentative time frame for each section in parenthesis)

1. **Introduction to Fuel Cells** (Week 1- W,F):
   i. Brief history of fuel cells
   ii. Operating principles
   iii. Differences between electrochemical and chemical energy conversion
   iv. Types of fuel cells (with an emphasis on PEMFC and DMFC technology)
   v. Applications
   vi. Current state of the art
   vii. Limitations and principle research areas (addressing limitations)

2. **Fuel Cell Thermodynamics** (Week 2):
   i. Brief review of first and second law of thermodynamics
   ii. Application of the first and second law to fuel cells
   iii. Significance of the Gibbs free energy
   iv. Concept of chemical potential and emf
   v. Derivation of the Nernst equation
   vi. Fuel cell efficiencies, comparison with Carnot efficiencies
   vii. Thermodynamic advantage of electrochemical energy conversion

3. **Some Concepts of Electrochemistry** (Week 3):
   i. Brief review of electrochemical concepts
   ii. Electrochemical cells, oxidation and reduction processes
   iii. Half cell potentials and the electrochemical series
   iv. Faraday’s law, faradaic and nonfaradaic processes
   v. Important factors involved in faradaic processes
   vi. Current and reaction rate
   vii. Polarization and overpotential
   viii. Cell resistance
   ix. Mass transport in electrochemical cells
   x. Important electrochemical experiments (linear sweep voltammetry, cyclic voltammetry)

4. **Electrode Kinetics** (Week 4):
   i. Requirements of kinetic theories
   ii. The Arrhenius equation
   iii. Equilibrium and electrode reactions – the Nernst equation
   iv. Current - potential dependency – the Tafel equation
   v. The Butler – Volmer theory for electrode kinetics
   vi. The intrinsic (standard) rate constant and the transfer coefficient
   vii. The exchange current
viii. The current - overpotential equation – limiting cases, Tafel and exchange current plots
ix. Mass transport effects

5. Irreversibility and Sources of Overpotential (Week 5):
   i. Irreversibility in the working fuel cell
   ii. Ideal current – voltage relationship in fuel cells
   iii. Sources of overpotential, discussion of various overpotentials:
      a. Activation polarization
      b. Ohmic polarization
      c. Concentration polarization
   iv. Actual current – voltage relationship – the polarization curve - simplified mathematical treatment
   v. Estimating the contribution of individual overpotentials – mathematical treatment
   vi. Temperature and pressure effects

6. Fuel Cell Electrolytes – the ionomeric membrane (Week 6):
   i. Different fuel cell technologies – electrolytes used
   ii. The ionomeric membrane in a PEM fuel cell
   iii. Properties (requirements) of ionomeric membranes
   iv. Mechanisms of proton transport in ionomeric membranes
   v. Water content and transport in ionomeric membranes
   vi. Relationship between proton conductivity and membrane water content
   vii. Ionomer in the electrode layers – the membrane electrode interface

7. Fuel Cell Electrocatalysis (Emphasis on PEMs) (Weeks 7, 8):
   i. Different fuel cell technologies – catalysts used
   ii. Hydrogen oxidation (anode) electrocatalysis in a PEM Cell
   iii. Effect of impurities on anode electrocatalysis in a PEM Cell
   iv. Oxygen reduction (cathode) electrocatalysis in a PEM Cell
   v. Electrocatalysts used at the anode and cathode in a PEM Cell – supported and unsupported catalysts
   vi. The electrode structure – importance of three phase contact
   vii. Half cell experiments to estimate catalytic activity – Voltammetry
   viii. Full cell experiments to determine cathode catalytic activity and anode polarizazion – Voltammetry
   ix. Arriving at an optimal electrode structure – parameters to be evaluated

8. The Membrane Electrode Assembly (MEA) (Week 9):
   i. Catalysts applied directly to membrane
   ii. Catalysts applied as a gas diffusion electrode
iii. Heat treatment
iv. Merits and demerits of above approaches
v. Improving interfacial stability and MEA endurance – alternate fabrication techniques

9. The Gas Diffusion Layer (GDL) and Flowfields (Week 10):
   i. Need for GDLs
   ii. Properties of a good GDL
   iii. Carbon paper and modified GDLs
   iv. Different types of flowfields
   v. Pressure drop, convection and diffusion of reactant gases

10. The Complete Picture (Week 11):
    i. Integration of individual components of the MEA
    ii. Fuel cell stacks
    iii. Fuel processing systems – a review
    iv. Humidification
    v. Inverters – converting DC to AC
    vi. Cogeneration
    vii. Limitations of existing technology:
        a. Fuel contamination (CO poisoning)
        b. Water management
        c. System complexity
        d. Cost
    viii. Approaches to improve technology

11. High Temperature PEMFC Operation (Week 12):
    i. Relationship between temperature and humidity
    ii. Rationale for high temperature, low relative humidity operation – emphasis on improved CO tolerance and easier water management
    iii. Perceived advantages of high temperature operation
    iv. Technical limitations – dehydration of ionomeric membrane
    v. Approaches adopted to overcome limitations – composite membranes, improved electrode and GDL structures
    vi. Current research areas and opportunities

12. Direct Methanol Operation (Week 13):
    i. Rationale – simplified fuel processing system
    ii. Mechanism of methanol electrooxidation
    iii. Similarity between CO poisoning and methanol electrooxidation
    iv. Approaches to improve methanol electrooxidation kinetics
    v. Methanol crossover
vi. Approaches to reduce methanol crossover – blended membranes, layered membranes, composite membranes
vii. Current research areas and opportunities

13. **PEMFC / DMFC Applications** (Week 14):

   i. In automobiles
   ii. For stationary power
   iii. For mobile units (such as cellular phones)

**Proposed Evaluation Scheme**

1. Laboratory reports, homework and assignments: 50%
2. Midterm Examination: 25%
3. Final Examination (or term paper): 25%