HYDROGEN AND FUEL CELL
ENCH 425

Lecture: 3 **Year: IV**
Tutorial: 2 **Part: I**
Practical: 1

Course Objectives:

The objective of this course is to introduce students to hydrogen economy concepts and the hydrogen value chain, while analyzing hydrogen production, storage and transport technologies. It enables students to evaluate the thermodynamics and electrochemical principles of fuel cells, perform basic fuel cell design and system integration and apply safety standards and economic analysis to hydrogen systems.

1. Hydrogen Economy and Fundamentals (3 hours)

1.1. Global energy scenario and decarbonization
1.2. Hydrogen as an energy carrier vs fuel
1.3. Hydrogen value chain
1.4. Physical and thermodynamic properties of hydrogen

2. Hydrogen Production Technologies (10 hours)

2.1. Conventional Methods: Steam Methane Reforming (SMR) , Partial Oxidation (POX), Autothermal Reforming (ATR)
2.2. Electrochemical Methods: Alkaline Electrolysis, Proton/Polymer Exchange Membrane (PEM) Electrolysis, Solid Oxide Electrolysis
2.3. Advanced Methods: Photo-electrochemical water splitting, Biomass gasification
2.4. Engineering Analysis: Energy efficiency comparison, Carbon footprint (Green vs Blue vs Grey hydrogen), Process flow diagrams

3. Hydrogen Storage and Transport (4 hours)

3.1. Compressed gas storage systems
3.2. Cryogenic liquid hydrogen storage system
3.3. Solid-state storage: Metal hydrides, Chemical carriers (ammonia, Liquid Organic Hydrogen Carrier (LOHCs))
3.4. Pipeline transport and leakage issues, Hydrogen embrittlement

4. Thermodynamics and Electrochemistry of Fuel Cells (4 hours)

2.1 Fuel cell thermodynamics (ΔG, ΔH, reversible voltage)
2.2 Nernst equation and polarization losses
2.3 Electrochemical kinetics (activation, ohmic, concentration losses)
2.4 Fuel cell efficiency and voltage-current characteristics

5. Fuel Cell Types and Materials (10 hours)

5.1. PEM Fuel Cells (PEMFC), Solid Oxide Fuel Cells (SOFC), Alkaline (AFC), Molten Carbonate (MCFC), Phosphoric Acid (PAFC)
5.2. Materials Focus: Catalysts (Pt, non-Pt), Electrolytes (polymer, ceramic), Bipolar plates
5.3. Performance Comparison: Temperature range, Efficiency
5.4. Applications

6. Fuel Cell Design and System Integration (7 hours)

6.1. Consideration for Fuel cell stack design
6.2. Membrane Electrode Assembly (MEA), Flow field design
6.3. Water management, Balance of Plant (BoP): Compressors, Cooling systems
6.4. Engineering Aspects: Scale-up challenges, System efficiency

7. Safety, Codes and Standards (3 hours)

7.1. Hydrogen safety hazards: Flammability limits, Explosion risks
7.2. Storage and handling standards, ISO hydrogen standards
7.3. National Fire Protection Association (NFPA) 2, Society of Automotive Engineers (SAE) hydrogen fueling protocols, International Electrotechnical Commission (IEC) fuel cell standards
7.4. Leak detection systems

8. Economics, Policy and Applications (4 hours)

8.1. Levelized Cost of Hydrogen (LCOH), Cost of fuel cells vs batteries
8.2. Policy frameworks and incentives, Green hydrogen prospects in Nepal,
8.3. Hydropower-based hydrogen production, Techno-economic case study (fertilizer)
8.4. Applications

Tutorial (30 hours)

1. Performing calculations to determine electrolyzer efficiency.
2. Calculating voltage losses in fuel cells.
3. Solving sizing problems for hydrogen storage systems.
4. Evaluating engineering considerations for fuel cell design.
5. Estimating the levelized cost of hydrogen through tutorial exercises.

Practical (15 hours)

1. Producing hydrogen through water electrolysis.
2. Testing the performance of a proton exchange membrane fuel cell.
3. Determining the operational efficiency of a fuel cell.
4. Analyzing the effect of varying operating conditions on fuel cell performance.
5. Simulating and integrating a complete hydrogen-fuel cell system.

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks
1	3	4
2	10	12
3	4	6
4	4	6
5	10	12
6	7	10
7	3	4
8	4	6
Total	**45**	**60**

*There may be minor deviation in mark distribution.

References:

1. Dicks, A. L., & Rand, D. A. J. (2018). Fuel cell systems explained (Latest ed.). John Wiley & Sons.
2. Hacker, V., & Mitsushima, S. (Eds.). (2018). Fuel cells and hydrogen: From fundamentals to applied research. Elsevier.
3. International Energy Agency. (2021). Global hydrogen review. IEA Publications.
4. O'Hayre, R., Cha, S. W., Colella, W., & Prinz, F. B. (2016). Fuel cell fundamentals (Latest ed.). John Wiley & Sons.
5. Sørensen, B., & Spazzafumo, G. (2018). Hydrogen and fuel cells: Emerging technologies and applications (Latest ed.). Academic Press.

POLYMER ENGINEERING
ENCH 426

Lecture : 3 **Year : IV**
Tutorial : 2 **Part : I**
Practical : 1

Course Objectives:
The objective of this course is to equip students with foundational knowledge of polymer chemistry, structure-property relationships, polymerization mechanisms and polymer rheology. It enables students to analyze primary and secondary polymer processing methods, evaluate composite materials and apply sustainable and advanced polymeric solutions to industrial applications.

1 Introduction and Fundamentals (3 hours)

1.1 Definition of polymers: macromolecules, degree of polymerization (DP), repeating units
1.2 Classification of polymers by origin (natural, synthetic, semi-synthetic), by chain structure (linear, branched, crosslinked), by thermal behavior (thermoplastics, thermosets, elastomers), by monomer composition (homopolymers, copolymers)
1.3 Nomenclature and stereochemistry: tacticity (isotactic, syndiotactic, atactic), regiochemistry

2 Polymerization Chemistry (6 hours)

2.1 Step-growth (condensation) polymerization: Mechanisms, equilibrium considerations, Carothers equation, Molecular weight control, stoichiometric imbalance effects
2.2 Chain-growth (addition) polymerization: Free radical (initiation, propagation, termination, chain transfer, kinetics), Ionic (anionic, cationic), coordination (Ziegler-Natta, metallocene, Philips)
2.3 Copolymerization: reactivity ratios, composition drift, instantaneous vs. cumulative composition
2.4 Polymerization techniques: Bulk, Solution, Solid-State, Gas Phase Plasma Polymerization

3 Polymer Molecular Weight and Characterization Techniques (6 hours)

3.1 Molecular weight distribution: number-average, weight-average, polydispersity index

3.2 Measurement of molecular weights: Absolute methods (osmometry, light scattering, ultracentrifugation), Relative methods (intrinsic velocity), melt flow index, Gel Permeation Chromatography (GPC)
3.3 Spectroscopic methods: FTIR, XRD, NMR
3.4 Thermal analysis: Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA), Dynamic Mechanical Analysis (DMA

4 Mechanical, Thermal and Physical Properties (4 hours)

4.1 Stress-strain behavior (elastic, plastic, viscoelastic)
4.2 Creep, stress relaxation, fatigue, fracture mechanics
4.3 Thermal transitions, Glass transition temperature, melting temperature, crystallinity, degradation, aging, water permeability

5 Polymer Rheology and Viscoelasticity (4 hours)

5.1 Non-Newtonian flow behavior of polymer melts/solutions
5.2 Viscoelastic models (Maxwell, Voigt, Burgers model)
5.3 Shear thinning, extensional viscosity, normal stresses
5.4 Rheological measurements (capillary, rotational rheometers, melt flow indexer)

6 Polymer Processing (12 hours)

6.1 Rheology-processing relationships
6.2 Processing techniques: Extrusion, Injection molding, Blow molding, Thermoforming and vacuum forming, Compression and transfer molding, Rotational molding, calendaring, Fiber spinning, Hand-spray layup, Compression molding, Injection molding, Reaction injection molding, Autoclaving, Resin transfer molding, Filament winding, Pultrusion, Sheet molding, Pre-pegging and challenges in primary processing of composites
6.3 Processing of Films: Principle, technology and operation of equipment
6.4 Compounding: additives (plasticizers, stabilizers, antioxidants, fillers, reinforcements, colorants)

7 Advanced Topics (10 hours)

7.1 Polymer composites and nanocomposites: fiber-reinforced, particulate-filled, layered silicates
7.2 Polymer degradation and stabilization: thermal, oxidative, photo, environmental
7.3 Sustainable polymers: biopolymers, recycling (mechanical, chemical), upcycling
7.4 Functional polymers: conducting polymers, stimuli-responsive, biomedical (hydrogels, drug delivery)

7.5 Secondary processing of polymer composites: Joining of polymer composites, Adhesive joining, Mechanical joining, Microwave joining, Induction and resistance welding, Drilling of polymer composites

Tutorial **(30 hours)**

1. Problems related to nomenclature and stereochemistry
2. Polymerization techniques mechanism, example problems and reactivity ratios
3. Numerical problems on molecular weight distribution: number-average, weight-average, polydispersity index
4. Study of properties and characterization of polymers
5. Numerical problems related to polymer rheological measurements
6. Case studies in relationship between polymer rheology and processing techniques
7. Research study on polymer composites andamp; nanocomposites
8. Research study on biopolymers, recycling and upcycling
9. Case study on rheology-processing relationships

Practical **(15 hours)**

1. Identification, physical and mechanical testing of common plastics
2. Study of effect of polymeric properties on processing technique
3. Fabrication of nonwoven yarn from thermoplastic polymer
4. Study of the effect of crosslinking on polymeric materials
5. Fabrication of thin film from solvent casting and study its hydrophobicity
6. Determination of melt flow index for different grades of a polymer

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	3	4
2	6	8
3	6	8
4	4	5
5	4	5
6	12	16
7	10	14
Total	**45**	**60**

* There may be minor deviation in marks distribution.

Reference

1. Fried, J. R. (2014). Polymer science and technology (Latest ed.). Prentice Hall.
2. Ebewele, R. O. (2000). Polymer science and technology. CRC Press.
3. Kaufman, H.S., Falcetta, J. J. (2010). Introduction to polymer science and technology. SPE Textbook, John Wiley and Sons.
4. Carraher, C. E., Jr. (2012). Introduction to polymer chemistry (Latest ed.). CRC Press.
5. Debnath, K., Singh, I. (2018). Primary and Secondary Manufacturing of Polymer Matrix Composites. CRC Press.

MINING AND MINERAL ENGINEERING

ENCH 427

Lecture : 3 **Year : IV**
Tutorial : 2 **Part : I**
Practical : 1

Course Objectives:
The objective of this course is to introduce students to the fundamental concepts of the global and Nepalese mining industries, geology of mineral deposits, mine surveying and underground mine design. It enables students to evaluate mine management, economics, safety and mineral processing techniques while applying environmental reclamation strategies and regulatory frameworks to mineral resource development.

1 Mining Industry and its development (3 hours)

1.1 Overview of the global mining industry
1.2 Basic concept of the mining industry
1.3 Characteristics of mining industry and associated risks

2 Mining geology and mineral formation (6 hours)

2.1 Crystal, mineral, rock and ore
2.2 Major geological structures
2.3 Formation of mineral deposits
2.4 Geological criteria and guides for prospecting of mineral deposits
2.5 Mineral exploration stages and techniques

3 Underground mining methods and mine design (8 hours)

3.1 Classification and description of underground mining methods
3.2 Selection criteria for underground mining methods
3.3 Mine development requirements
3.4 Principles of mine surveying and underground mine design

4 Mine management and mine economics (5 hours)

4.1 Mine economics and mine valuation
4.2 Mining costs and cost-benefit analysis
4.3 Mine planning including lightning, drainage and ventilation
4.4 Tailings disposal and dewatering management

5 Mineral processing and ore beneficiation (8 hours)

5.1 Scope and objectives of mineral processing
5.2 Basics of ore handling and sampling theory

5.3 Crushing, grinding and beneficiation techniques
5.4 Selection of concentration methods and equipment
5.5 Industrial importance of mineral processing

6 Mine Health, safety and risk management (5 hours)

6.1 Mine atmosphere and mine gases
6.2 Fire, explosion and inundation hazards
6.3 Dust monitoring and control
6.4 Heat, humidity and control
6.5 Equipment hazards, noise control and safety measures

7 Environmental management and Mine reclamation (5 hours)

7.1 Environmental impact of mining
7.2 Air, water and land pollution in mining operations
7.3 Environmental monitoring and control techniques
7.4 Mine reclamation and sustainable mining practices
7.5 Environment protection act (2019)

8 Mineral resources and mining policy in Nepal (5 hours)

8.1 Potential mineral resources of Nepal
8.2 Current status of the mining industry in Nepal
8.3 Sustainable development of mineral resources
8.4 Nepalese act on mines and minerals

Field Work (3 days)

A three-day field visit will be conducted to provide practical on-site exposure to the identification of minerals and rocks, geomorphological features and geological structures, along with a visit to a selected mining industry to observe the mining process. Students are required to submit a fieldwork report after the visit. (Attendance in the fieldwork is compulsory).

Tutorial (30 hours)

1. Current status of mining industry of Nepal and compare it with another mining industry from other countries
2. Geological characteristics and formation of mineral deposits in Nepal with discussion on exploration methods uses in Nepal and internationally
3. Selection and comparison of underground mining methods suitable for Himalayan geological condition with reference to mines in Nepal and aboard
4. Economic evaluation and feasibility analysis of mining project considering mining costs, market demand and cost-benefit analysis
5. Environmental management, mine safety practices and mine reclamation strategies in Nepalese mining operations with reference to international standards

6. Analysis of mineral exploration techniques used in Nepal including geological mapping, geophysical surveys and drilling methods
7. Study of mine ventilation, drainage and lightning systems required for safe underground mining operations with references to practices used in Himalayan mining environments
8. Review of Nepal's mines and Mineral Act and Environmental Protection Act with discussion on their role in regulating mineral resource development and environmental protection.

Practical **(15 hours)**

1. Study of industrial minerals in hand specimens.
2. Study of ores in hand specimens.
3. Study of common rocks in hand specimens.
4. Preparation of mineral maps of Nepal.
5. Estimation of limestone reserves based on borehole data.
6. Mine planning
7. Study of the particle size distribution of a sand sample.

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	3	6
2	6	6
3	8	12
4	5	6
5	8	12
6	5	6
7	5	6
8	5	6
Total	**45**	**60**

* There may be minor deviation in marks distribution.

Reference

1. Ray, S.C., Sinha, I.N. (2016). Mine and Mineral Economics. PHI Learning Pvt. Ltd., Delhi.
2. Kreiter, V.M. (2004). Geological Prospecting and Exploration. University Press of the Pacific.
3. Jensen, M.L., Bateman, A.M. (1979). Economic Mineral Deposits. Wiley, New York.
4. Harman, H.L., Mutmansky, J.M. (2002). Introductory Mining Engineering. John Wiley, New Jersey.
5. Wills, B.A., Finch, J. (2006). Wills' Mineral Processing Technology: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery. Elsevier Science & Technology Books.

PHARMACEUTICAL ENGINEERING
ENCH 428

Lecture : 3 **Year : IV**
Tutorial : 2 **Part : I**
Practical : 1

Course Objectives:
This course introduces the principles of pharmaceutical engineering with emphasis on the application of chemical engineering concepts in pharmaceutical manufacturing like pharmaceutical unit operations, solid and liquid dosage form production, sterile processing, process validation, quality control and plant utilities.

1 Introduction to Pharmaceutical Engineering and Industry (8 hours)

1.1 Overview of the pharmaceutical industry in Nepal
1.2 Drug development process: Discovery, Preclinical, Commercialization
1.3 Introduction to Drug Act and regulations of Nepal
1.4 Good Manufacturing Practices (GMP)
1.5 Introduction to green chemistry and sustainable pharmaceutical manufacturing

2 Pharmacokinetics and Drug Delivery System (12 hours)

2.1 Basic Pharmacokinetics and Pharmacodynamics
2.2 Compartment modeling (one-and-two-compartment models)
2.3 Bioavailability and bioequivalence
2.4 Conventional dosage forms (solid, liquid, semi-solid, parenteral)
2.5 Controlled and Modified Release Systems
2.6 Targeted and novel drug delivery systems

3 Pharmaceutical Unit Operations (10 hours)

3.1 Size reduction, Size separation, Mixing, Filtration, Drying
3.2 Solid Dosage Form Manufacturing
3.3 Liquid and sterile Dosage Form Manufacturing
3.4 Aseptic Processing and amp; Sterilization techniques

4 Bioprocess and Biopharmaceutical Engineering (10 hours)

4.1 Introduction to Biopharmaceuticals
4.2 Fermentation Technology
4.3 Downstream Processing
4.4 Monoclonal Antibodies and Vaccine Production
4.5 Introduction to gene therapy and cell therapy

5 Process Engineering, validation and Quality Control (10 hours)

5.1 Process Scale-Up and Technology Transfer
5.2 Process Validation (IQ, OQ, PQ)
5.3 Quality Control and quality assurance
5.4 Clean room design and contamination control
5.5 Pharmaceutical plant utilities (HVAC and water systems)

Tutorial (30 hours)

1. Classroom activities and case studies on the pharmaceutical industry, drug development process, Good Manufacturing Practices (GMP), pharmaceutical regulations in Nepal and sustainable pharmaceutical manufacturing.
2. Discussion on green chemistry principles and sustainable pharmaceutical manufacturing practices.
3. Conceptual exercises on pharmacokinetics, pharmacodynamics and compartment models.
4. Classroom activities on bioavailability, bioequivalence, dosage forms and drug delivery systems.
5. Problem-solving and discussions on pharmaceutical unit operations including size reduction, mixing, filtration and drying.
6. Exercises on the manufacturing processes of solid, liquid and sterile dosage forms with aseptic processing concepts.
7. Discussion on biopharmaceuticals, fermentation technology and downstream processing.
8. Classroom activities on monoclonal antibody production, vaccine manufacturing, gene therapy and cell therapy.
9. Case studies on process scale-up, technology transfer, process validation and quality assurance.
10. Discussion and case studies on cleanroom design, contamination control, pharmaceutical plant utilities and overall course revision.

Practical (15 hours)

1. Determination of Particle Size Distribution of Pharmaceutical Powders by Sieve Analysis
2. Preparation and Evaluation of Pharmaceutical Granules by Wet Granulation Technique
3. Evaluation of Flow Properties of Pharmaceutical Powders (Angle of Repose, Bulk Density, Tapped Density, Carr's Index and Hausner Ratio)
4. Evaluation of quality parameter of tablets dosage form (hardness, friability, disintegration test)
5. Evaluation of physicochemical quality parameters of a pharmaceutical syrup
6. Determination of assay of selected drug by UV-Visible Spectrophotometry method
7. Pharmaceutical industry visit and technical report writing

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	8	10
2	9	12
3	9	12
4	9	12
5	10	14
Total	**45**	**60**

* There may be minor deviation in marks distribution.

Reference

1. Remington, J.P. (2020). The Science and Practice of Pharmacy (Latest ed.). Pharmaceutical Press.
2. Jain, N.K., Sharma, S. (2016). Textbook of Professional Pharmacy (Latest ed.). Vallabh Publications.
3. Lachman, L., Lieberman, H.A. (2020). The Theory and Practice of Industrial Pharmacy (Latest ed.). CBS Publishers & Distributors Pvt. Ltd.
4. Jain, S.K., Soni, V. (2011). Bentley's Textbook of Pharmaceutics. Elsevier India.