PhD Qualifying Exam Topics
2013-14
Biotechnology:

Topics:

1. Biochemistry
2. Cell Biology
3. Molecular Biology
4. Genetics
5. Biostatistics

Text Books:

Chemistry:

Topics:

1. Organic Chemistry
2. Inorganic Chemistry
3. Analytical Chemistry
4. Biochemistry
5. Physical Chemistry
Computer Science:

Topics:

1. Artificial Intelligence
   a. Fundamental Issues:
      • Overview of AI problems, Examples of successful recent AI applications
      • What is intelligent behavior?
      • Nature of environments
      • Nature of Agents
   b. Basic Search Strategies
      • Problem spaces (states, goals and operators), problem solving by search
      • Factored representation (factoring state into variables)
      • Uninformed search (breadth-first, depth-first, depth-first with iterative deepening)
      • Heuristics and informed search (hill-climbing, generic best-first, A*)
      • Space and time efficiency of search
   c. Basic Knowledge Representation and Reasoning
      • Review of propositional and predicate logic
      • Resolution and theorem proving, unification and lifting
      • Forward chaining, backward chaining

2. Algorithms and Computability Theory
   a. Algorithms and Complexity
      • Analysis of Algorithms
      • Algorithmic Strategies
      • Fundamental Algorithms
      • Distributed Algorithms
      • Basic Computability
      • P versus NP
      • Automata Theory
      • Parallel Algorithms
   b. Discrete Structures
      • Functions Relations And Sets
      • Basic Logic
      • Proof Techniques
      • Basics Of Counting
      • Graphs And Trees
      • Discrete Probability
   c. Computability Theory
• Sets and languages
• Deterministic finite automata (DFAs)
• Nondeterministic finite automata (NFAs)
• Equivalence of DFAs and NFAs
• Regular expressions
• Equivalence of regular expressions and finite automata
• Closure properties
• Context-free grammars
• Push-down automata (PDAs)
• Relationship of PDAs and context-free grammars
• Properties of context-free languages
• Turing machines
• Nondeterministic Turing machines
• Chomsky hierarchy
• The Church-Turing thesis
• The halting problem

3. Computer Architecture

• Fundamentals of Computer Design
• Instruction Level Parallelism
• Memory Hierarchy design
• Limits on instruction Level Parallelism
• Multiprocessors and thread level parallelism
• Multicore computing

4. Distributed Systems

• Characterization of Distributed Systems
• System Models
• Interprocess Communication
• Remote Invocation
• Indirect Communication
• Operating System Support for Distributed Systems
• Distributed Objects and Components
• Distributed File Systems
• Time and Global States
• Coordination and Agreement

5. Programming Languages and their Implementations

• Object-Oriented Programming
• Functional Programming
• Event-Driven and Reactive Programming
• Basic Type Systems
• Program Representation
• Language Translation and Execution
• Syntax Analysis
• Compiler Semantic Analysis
• Code Generation
• Runtime Systems
• Static Analysis
• Advanced Programming Constructs
• Concurrency and Parallelism
• Type Systems
• Formal Semantics
• Language Pragmatics
• Logic Programming

Text Books:

4. Kenneth Louden, Compiler Construction: Principles and Practice, PWS publishing company, Chapters 1-6, and 8
Construction Engineering:

Topics:

1. Construction Management and Technology
2. Construction Materials and Structures
3. Environmental Engineering

Text Books:
TBA
Electronics Engineering:

Topics:

1. Engineering Math
2. Electronic Devices
3. Integrated Circuits
4. Computer Networks
5. Digital Systems
6. Electromagnetics
7. Linear Systems and Communications
8. Probability and Random Processes

The exam will have 8 sections and each student is expected to answer 4 sections.

Text Books:

The list will be announced before each exam.
Environmental Engineering:

Topics:

Core topics:

1. Unit Operations for water and wastewater treatment
2. Water Quality modeling and Control
3. Specialization topics (vary with student):
4. Air Pollution Control Engineering (for mechanical engineer)
5. Solid and Hazardous Wastes Engineering (For civil and construction engineers)

Background Topics (three areas):

6. Statistics
7. Environmental Chemistry
8. Surface and Groundwater Hydraulics
9. Groundwater Hydrology and Contamination
10. Environmental biology

Text Books:

Textbooks are to be suggested after selecting the topics.
Mechanical Engineering:

Core Topics:

1. Fundamental engineering theories in:
   a. Materials engineering
   b. Manufacturing
   c. Mechanics of solids
   d. Mechanical design
   e. Thermodynamics
   f. Fluid mechanics and heat transfer
   g. System dynamics
   h. Production management and quality control.
2. Fundamental engineering methodologies, including: applied engineering mathematics (calculus, linear algebra, differential equations), optimization methods, numerical analysis, computational methods, probability and statistical analysis techniques.

Specialization Topics:

1. Design and mechanics
2. Industrial Engineering
3. Materials and manufacturing
4. Mechatronics
5. Power

Text Books:
The list will be announced before each exam.
Nanotechnology:

Topics:

1. Nanomaterials (Drs. Salem, Mamdouh)
   a. Materials classification, general properties compared to conventional materials [NANO 531, MENG 327]
   b. Nanomaterials Synthesis, processing (top-down vs. Bottom up) [NANO 531]
   c. Nanomaterials characterization methods [NANO 503]
   d. Nanomaterials mechanical, Physical, Optical, etc. properties and testing [NANO 531]
   e. Nanomaterials application [NANO 531]
   f. Nanomaterials Vs. Nanostructured Materials Selection and comparison between a number of different nanomaterials (how to select a nanomaterial for a given application) [NANO 531]
   g. Nanopowder synthesis and refinement via Top-down and Bottom-up methods, [NANO 531, NANO 532]
   h. Nanocomposites Synthesis, processing [NANO 532]
   i. Types of Nanocomposites and design criteria [NANO 532]
   j. Thin films and coatings [NANO 532]

2. Nanostructured Materials for Solar Energy Conversion (Dr. Allam) [NANO 533/592]
   a. Physics of Nanomaterials
   b. Thermodynamics/Kinetics of Nanomaterials
   c. Band Theory of Solids
   d. Semiconductor Physics
   e. Light-Matter Interaction, absorption, emission, etc
   f. Photoelectrochemistry

3. Nanochemistry (Drs. Madkour, Mamdouh, Ragai, Ramadan; NANO 505, 541, 542, 641)
   a. Size-dependence of different physicochemical properties and how they vary with the reduction at the nanoscale; focus on properties of significance: band structures, surface properties, reactivity, optical properties, conductivity, magnetism
   b. Sol-gel methods for the synthesis of nanostructures
   c. Chemical vapor deposition for the synthesis of nanostructures
   d. Soft and hard templating for the synthesis of nanostructures and assemblies
   e. Chemical self-assembly for the synthesis of nanostructures
   f. Soft lithography and dip-pen nanolithography for synthesis of nanostructures
   g. Synthesis methods, molecular structure, physicochemical properties of carbon-based nanostructures: carbon-nanotubes, fullerenes
h. Categories, synthesis methods, and physicochemical properties of SAMs
i. Structures and physicochemical properties of ferrofluids
j. Synthesis methods, structures and physicochemical properties of dendrimers
k. Synthesis methods, structures and physicochemical properties of metallic and inorganic nanotubes, nanorods and nanofibers
l. Categories, synthesis methods and physicochemical properties of nanoporous materials
m. Categories, synthesis methods and physicochemical properties of bulk nanostructures
n. Fundamentals of electrochemistry: electrochemical assemblies, electrode potentials, thermodynamics of electrochemical systems (optional)
o. Electrode-electrolyte interface: structure, electrochemical nanostructuring (optional)
p. Nanostructures in electrochemical assemblies (optional)
q. The application of probe microscopies in the electrochemical control, synthesis and characterization of nanostructures and assemblies (optional)
r. Characterization of ordered and amorphous nanoporous materials by physisorption (optional)
s. Synthesis of nonporous materials: ordered, amorphous, surface functionalized, CNTs, PIMs (optional)
t. Applications of nanoporous materials in catalysis: acid-base, redox, enantioselective catalysis (optional)
u. Applications of nanoporous materials in bioabsorption and separation (optional)
v. Applications of nanoporous materials (PIMs) in pollutant removal and gas separation (optional)

4. High performance circuit and interconnect design and modeling (Dr. Anis)
   a. VLSI devices and modeling
   b. Basic VLSI digital and analog circuits
   c. Basic VLSI System design

5. Nanophotonics: (Dr. Swillam), NANO 621
   a. Electromagnetic theory
   b. Maxwell equation in linear and nonlinear media
   c. Wave equation in waveguides
   d. Principle of optics, Quantum mechanics
   e. Semiconductor physics
   f. Linear algebra
   g. Numerical approximation methods of partial differential equations
   h. Computational methods for wave equation and Maxwell equations
   i. Lasers and detectors.
6. Nanophysics: (Dr. Swillam)
   a. Electromagnetic theory
   b. Semiconductor physics
   c. Quantum mechanics
   d. Classical mechanics
   e. Computational physics
   f. Nanomaterials properties
   g. Physics of nanotechnology
   h. Thermodynamics
   i. Solid state physics
   j. Principle of optics
   k. Optical properties of semiconductors.

7. Microfabrication and Devices: (Dr. Serry)
   a. MEMS Technology and Devices (NANO 521)
   b. Microfabrication Technology (NANO 504)
   c. Transport Phenomena in Semiconductors (NANO 522)
   d. Modeling of physical systems
   e. Modern Sensors
   f. Advanced Testing and Characterization Techniques (NANO 503)
   g. Elective 1: Mechanics of Materials or - Surface Chemistry
   h. Elective 2: Thermodynamics or Quantum Mechanics

8. Modeling and Simulation of Nanomaterials and devices (Dr. Khodary)

   a. Classical mechanics (Free body diagrams, Newton's laws, Lagrangian formulation, Legendre transform, Hamiltonian formulation, phase space, configuration space, Lagrange multipliers and constraints)
   b. Potential functions (e.g. Lennard Jones, embedded atom model, Morse, force field ...)
   c. Introduction to Statistical mechanics (Canonical and Microcanonical ensembles, partition functions, phase space integrals)
   d. Introduction to Thermodynamics (zeroth, first, second and third laws; meaning of Entropy, free energy,...; relation to statistical mechanics ..)
   e. Nano-Simulation
   f. Molecular Dynamics; algorithms and applications (Verlet algorithm, MATLAB nonlinear solvers, LAMMPS)
   g. Acceleration methods for molecular dynamics (parallel replica, thermally accelerated dynamics, hyperdynamics)
   h. Kinetic Monte Carlo
   i. Introduction to Lattice dynamics

General Background:
• MATLAB, FORTRAN and/or C (C++) programming. (CSCI 106, ENGR 313)
• MATH: Vector calculus, partial differential equations, minimization of convex functions, integral transforms, some numerical analysis (Newton-Raphson, ...) (MACT 231, ENGR 313, possibly ENGR 517)

**Text Books:**

Each topic corresponds (linked directly) to one or two of the courses, which course material and assigned textbooks and references will be the ones referred to by the student.
Robots, Control, and Smart Systems:

Topics:

1. Logic Design
2. Real Time Embedded systems
3. Modern Control Engineering
4. Robotics: Design and Analysis
5. Pneumatic Control
6. Electro-Mechanical System Design
7. Probability and Random Process
8. Smart Systems and Computational Intelligence

Text Books:
The list will be announced before each exam.