

# Ph.D. Written Examination Syllabus

August 11, 2016

## 1 Analysis of Algorithms

### Syllabus

*Philosophy:* We are testing analytical ability: how well students think on their feet, rather than details of some data structure, etc. So there will be less reliance on memory. The questions will be more of a general nature (and will require more analytical/creative ability) than a typical final exam.

All sections marked with a \* in CLRS (4.4, 5.4, 11.5, 12.4, 16.4, 16.5, 21.4, 26.4, 26.5) are excluded.

#### 1. Preliminaries (CLRS Chapters 3 and 4):

- pages 21, CLRS Ch 3 Growth of Functions
- pages 29, CLRS Ch 4 Recurrences
- pages 30, CLRS Ch 5 Probabilistic Analysis and Randomized Algorithms
- pages 6, CLRS Ch C.3 Discrete random variables
  
- Algorithm growth, Big-Oh and similar notations.
- Recurrence equations, and their solution. Applications of recurrences.
- Randomized algorithms, expected runtime analysis

#### 2. Sorting (CLRS Chapters 6-9):

- pages 18, CLRS Ch 6 Heapsort
- pages 20, CLRS Ch 7 Quicksort
- pages 18, CLRS Ch 8 Sorting in Linear Time
- pages 13, CLRS Ch 9 Medians and Order Statistics
  
- Algorithms (Heapsort, quicksort, mergesort, radixsort).
- Proof that sorting (by comparisons) takes  $\Omega(n \log(n))$  time.

- Medians and order statistics.
3. Divide and conquer techniques (CLRS Section 2.3, Chapter 7, and Section 28.2):
- pages 10, CLRS Section 2.3 Designing Algorithms
  - pages 20, CLRS Ch 7 Quicksort
  - pages 7, CLRS Section 28.2 Strassen's algorithm
  - For mergesort.
  - For quicksort.
  - Strassen's algorithm for matrix multiplication.
4. Trees and hashing (CLRS Chapters 10–14 and 18):
- pages 21, CLRS Ch 10 Elementary Data Structures
  - pages 42, CLRS Ch 11 Hash Tables
  - pages 20, CLRS Ch 12 Binary Search Trees
  - pages 29, CLRS Ch 13 Red-Black Trees
  - pages 21, CLRS Ch 18 B-trees
  - pages 17, CLRS Ch 14 Augmenting Data Structures
  - Stacks, queues, linked lists.
  - Hashing techniques and functions.
  - Binary search trees.
  - Balanced search trees.
  - B-trees.
  - Dynamic order statistics, interval trees
5. Dynamic programming (CLRS Chapter 15):
- pages 47, CLRS Ch 15 Dynamic Programming
  - Examples and principles.
6. Greedy algorithms (CLRS Chapters 16 and 23);
- pages 25, CLRS Ch 16 Greedy Algorithms
  - pages 19, CLRS Ch 23 Minimum Spanning Trees
  - Huffman codes.

- Minimal spanning tree.
7. Graph algorithms (CLRS Chapters 22-26):
- pages 34, CLRS 22 Elementary Graph Algorithms
  - pages 19, CLRS 23 Minimum Spanning Trees
  - pages 40, CLRS 24 Single-Source Shortest Paths
  - pages 23, CLRS 25 All-pairs Shortest Paths
  - pages 56, CLRS 26 Maximum Flow
- Graph representations.
  - Graph traversals.
  - Spanning trees or forests.
  - Shortest paths.
  - Maximum flow.
8. Amortized Analysis (CLRS Ch 17)
- pages 25, CLRS 17 Amortized Analysis
  - Analyzing a sequence of operations
  - Aggregate, accounting, and potential methods
9. Data Structures for Disjoint Sets (CLRS Ch 21, excluding 21.4)
- pages 12, CLRS 21 (excluding 21.4) Data Structures for Disjoint Sets
  - Union/Find data structures
  - Linked list representations, disjoint forest representations
  - Union by rank, path compression
  - Runtime, but not the proof, of union by rank with path compression
10. NP-completeness (CLRS Chapter 34):
- pages 56, CLRS Ch 34 NP-Completeness
  - We won't ask students to prove how NP Turing Machines reduce to satisfiability, but they should be able to do simple reductions.
  - The classes P, NP, NP-complete, NP-hard.
  - An initial NP-complete problem.
  - Reductions and proofs that other problems are NP-complete, e.g., Hamiltonian Circuit, Traveling Salesman, and Vertex Cover.

## References

- Algorithms, by Cormen, Leiserson, Rivest, and Stein (CLRS) (the "green" book).

## 2 Operating Systems

### Syllabus

#### 1. Basic resource management:

- pages 95-128 SGG Ch 4 Processes
- pages 207-249 CDK Ch 6 Operating Systems Support
- pages 129-149 SGG Ch 5 Threads
- pages 151-188 SGG Ch 6 Process scheduling
- pages 273-316 SGG Ch 9 Memory Management
- pages 317-370 SGG Ch 10 Virtual Memory
- pages 371-409 SGG Ch 11 File System Interface
- pages 411-451 SGG Ch 12 File System Implementation

Total: 314 pages

Main Topics:

- Processes and process organization
- Threads versus processes
- Process scheduling
- Memory management and virtual memory
- Disk and storage management
- File systems

#### 2. Synchronization:

- pages 189-241 SGG Ch 7 Process Synchronization
- pages 243-270 SGG Ch 8 Deadlocks

Total pages: 82 pages

Main Topics:

- Mutual exclusion
- Mutex locks
- Semaphores
- Condition variables
- Classical synchronization problems
- Monitors
- Concurrency

- Deadlocks

### 3. Communication:

- pages 65-124, CDK Ch 3 Networking
- pages 125-164, CDK Ch 4 Interprocess Communication
- pages 165-203, CDK Ch 5 Distributed Objects and Remote Invocation
- pages 669-695, CDK Ch 17 Corba

Total Pages: 166

Main Topics:

- Connectionless versus connection-oriented protocols
- Blocking versus non-blocking
- Client-server model
- RPCs
- Remote object invocation
- CORBA
- Multicast
- Group communication
- Message passing

### 4. Naming, authentication, and protection

- pages 251-308, CDK Ch 7 Security
- pages 629-656, SGG Ch 18 Protection
- pages 353-384, CDK Ch 9 Name Services

Total: 118 pages

Main Topics:

- Basic security principles
- Authentication
- Digital signatures
- Public Key versus Shared Key
- Needham-Schroeder, Kerberos, SSL
- Domains
- Capabilities
- Name services and spaces
- DNS

- Directory services
- Discovery services

## 5. Distributed file systems

- pages 309-352, CDK CH 8 Distributed File Systems

Total: 44 pages

Main Topics:

- Design principles of distributed file systems
- NFS
- Andrew
- Caching
- Consistency
- Persistent stores

Operating Systems total: 724 pages

## References

- Operating System Concepts, 6th ed by Silberschatz, Galvin and Gagne (SGG)
- Distributed Systems, 3rd ed. by Coulouris, Dollimore, and Kindberg (CDK)