If you are ready for the Final Exam, you should be able to:

- describe the components of the internet according to the "nuts and bolts" model, including the role of each component.
- describe the role of the following components in the internet: protocol, network, hierarchy, standards, packet, router, communication link, application, connection-oriented service, connectionless service.
- identify the network components that belong to the core and to the edge of the internet.
- differentiate between circuit-switched and packet-switched networks, including the pros and cons of each, performance differences of each, and the mechanisms each use to share the network bandwidth.
- calculate end-to-end transmission time for data sent on a store-and-forward network with no delays.
- read, comment upon and review research papers with a strong process to store and search the knowledge gained from the paper.
- calculate delay in a packet-switched network as a sum of nodal processing delay, queueing delay, transmission delay and propagation delay.
- describe the algorithm used by traceroute to measure delay in real networks. Additionally, be able to use traceroute and interpret its output.
- argue the benefits of a layered architecture (as compared to monolithic).
- describe the internet's layered architecture according to the OSI model, including the mission of each layer, the scope of the layer, the type of data transferred by the layer and summary of the execution steps accomplished.
- describe the internet's layered architecture according to the TCP/IP model and argue the importance of architectural features of that model.
- explain the role of the IETF in the internet's operation.
- describe the goals of the TCP/IP design according to Clark88 and identify the fundamental goal.
- explain the ramifications of the robustness, multiple services and multiple networks goals on the design of the TCP/IP protocols.
- explain Saltzer84's "End-to-End" argument. Be able to describe exceptional situations where it may not apply as well as ways in which the modern internet may be moving away from this design philosophy.
- analyze business practices of various enterprises using the multi-tier network model (Tier-1, 2, etc) and common peering practices.
- describe the relationships and associated motivations for enterprises on the internet.
- analyze the effect of recent trends in internet usage patterns on the various business enterprises on the internet.

- describe interconnection methods between enterprise networks.
- describe the mission, scope, addressing mechanism and data types of the Application Layer.
- explain the HTTP protocol, including message format, interaction model and connection management.
- calculate response time for an HTTP request over nonpersistent, parallel or persistent connections, including the pipelined variant.
- describe how web proxies work to cache HTTP responses, including how they ensure consistency.
- describe the DNS service, including mission, interaction model, nameservers, domains, zones, load distribution, and domain name types.
- explain the DNS protocol, including message format, reliability, resource records, types, and caching mechanisms.
- describe the navigation mechanisms of DNS nameservers.
- describe the roles of the different nameservers in the DNS.
- describe how a CDN operates, including goals, host-roles, URL rewriting and DNS redirection.
- contrast the advantages of CDNs and web proxies.
- list reasons that led to the creation of P2P networks.
- describe what an overlay network is and how it is different from the internet.
- use historical P2P networks to describe centralized P2P networks, fully distributed P2P networks, hierarchical P2P networks.
- describe search techniques in the various P2P forms, and to analyze search efficiencies.
- describe the application of queuing theory to common networking problems.
- calculate simple queueing theory problems, including use of Little's law, M/M/1 and M/M/c measures of effectiveness. In such cases, all equations will be given.
- not memorize queueing theory equations.
- classify problems in terms of queueing system characteristics and know Kendall53 notation for those systems.
- describe the mission, scope, addressing mechanism, data types and responsibilities of the Transport Layer.
- explain UDP, including advantages/disadvantages, segment format, and reliability assumptions.
- calculate the checksum of a UDP segment.

- describe the purpose, limitations and variations in usage of each RDT tool--checksums, receiver feedback, retransmission, sequence numbers, timer expiration, window--as well as the network faults each is designed to overcome.
- describe and analyze RDT protocols (including Stop-n-Wait, Go Back N & Selective Repeat) in order to show how each RDT tool is employed.
- describe how changes to the employment scenario for a protocol affects the protocol design choices. An example is receiver-side buffering.
- describe the requirements and features of TCP.
- describe the segment format of TCP.
- calculate MSS from the relationship of MTU, Network and Transport header sizes.
- describe the operations behind establishing and tearing-down a TCP connection.
- describe the operation of sender and receiver in reliably transferring data across the TCP connection. This description should include events occurring at the sender (including fast retransmision optimizations) and receiver, as well as scenarios whereby error conditions are overcome.
- describe the mission, operation and mechanisms for flow control in TCP.
- list causes, costs and consequences of network congestion.
- describe the operations of, as well as advantages and disadvantages of, different feedback mechanisms.
- describe the overall congestion control mechanisms used in TCP, including the congwin variable, self-clocking nature, and interaction of various phases.
- describe the slow start component of TCP congestion control; including starting conditions, reactions to ACKs and ending conditions.
- describe the congestion avoidance component of TCP congestion control; including starting conditions, ending conditions, reactions to loss, reactions to ACKs and differences between Reno and Tahoe versions.
- describe how TCP sets timeout values.
- calculate EstimatedRTT, DevRTT and TimeoutInterval.
- describe features of the following TCP congestion control variations: New Reno, Vegas, Hybla, BIC and Compound TCP.
- describe the advantages and disadvantages of delay-based variants.
- describe the challenges of congestion control for LFNs.
- describe the problems and attractions of a non-cooperative TCP implementation.
- describe the mission, scope, addressing mechanism, data types and responsibilities of the Network Layer.
- describe the differences that would result from a connectionless or connection-oriented network.

- explain IPv4, including advantages/disadvantages, datagram format, and packet-handling operations at each router.
- calculate the packets that result from an IPv4 fragmentation scenario, including size, id, flags and offset fields.
- calculate IPv4 address ranges from prefix notation and be able to apply the longest matching prefix rule to forwarding decisions.
- apply route aggregation to prefix scenarios.
- describe ICMP, including packet format, use of type/code fields for ping, traceroute, and error situations.
- describe the differences between global / decentralized and static / dynamic routing algorithms. Students should be able to describe different message complexity, convergence speeds, robustness and algorithm complexity.
- calculate a forwarding table using Dijkstra's algorithm (which may include identifying and using proper variables and terms). Intermediate results may be required, such as an SPT or table of variable values.
- use Bellman-Ford equations to calculate a forwarding table for a DV routing algorithm. Intermediate values may be required, which may require knowing variable names and terms.
- describe how DV algorithms operate to pass updates.
- describe DV instability problems, such as "Count to Infinity" and the associated stabilization techniques.
- analyze DV instability examples.
- describe heirarchical routing and describe how it solves the scale and administrative autonomy problems of internet-scale routing.
- describe AS and ASNs, including common ASN scenarios.
- identify and describe the following IGPs: OSPF, IS-IS, RIP, EIGRP.
- describe the hierarchy features of OSPF.
- describe how the architecture of RIP allows it to use UDP.
- describe the mission, operation, operating state, neighbor relations and message types of BGP4.
- describe the use of the AS-PATH, NEXT-HOP, MED and LOCAL-PREF attributes.
- describe how BGP route announcements propagate through the network and show how the attributes are changed in response.
- describe how BGP interacts with the IGP to populate the forwarding table.
- describe BGP route processing inside the router, including how the router decides if it should "filter" a packet (hint: it never decides to "filter" a packet).

- describe DHCP, including information carried, methods of communication, leases, message format and the discovery process.
- describe NAT, including benefits / objections, operations and port forwarding.
- describe situations where NAT needs to modify values other than IP address and TCP/UDP port fields.
- describe IPv6, including differences with IPv4, benefits, datagram format, and address notation.
- describe IPv6 address autoconfiguration.
- describe the purposes of network measurement, both from a short-term and longer-term perspective.
- describe the uses of basic measurement tools (packet traces, SNMP counters, ping, traceroute).
- describe the use of netflow tools and how they differ from other measurement tools. Be able to solve problems requiring knowledge of the flow definition, flow record, sampling methods and flow aggregation.
- analyze a scenario to pick the most appropriate measurement tool.
- describe the differences between packet scheduling algorithms and drop policies.
- describe the algorithm and issues with the following queueing algorithms: FIFO, Priority Queueing, Round Robin, Fair Queuing and Weighted Fair Queueing.
- analyze a scenario using one of the following queueing algorithms: FIFO, Priority Queueing, Round Robin, Fair Queuing and Weighted Fair Queueing.
- describe the opportunities for a router to do congestion control.
- describe the goals and details of the RED Gateway algorithm, as well as its advantages when compared to FIFO or other queueing algorithsm.
- calculate average queue length and drop probability as the RED algorithm does.
- describe the mission, scope, addressing mechanism, data types and responsibilities/ services of the Data Link Layer.
- describe the differences between broadcast and point-to-point links.
- describe three different general types of media access protocols.
- describe the CSMA/CD protocol, including the details of Ethernet's implementation.
- use space-time diagrams to describe or solve problems relating to media access, including details of Ethernet's implementation.
- describe the Ethernet frame format.
- solve problems involving interaction of several Ethernet senders and receivers, collisions, propagation times, and the details of Ethernet's CSMA/CD algorithm.

- describe the Address Resolution Protocol, including it's mission, frame fields, transmission mechanism, caching, security, and gratuitous use.
- describe the mission, features and differences of these devices: repeater, hub, switch, and bridge.
- analyze and describe the self-learning capabilities of a switch for forwarding scenarios.
- describe the spanning tree protocol (IEEE 802.1D), including its distributed aspects.
- analyze a multi-switch/LAN scenario using the spanning tree protocol. Be able to step through the 4 phases of this algorithm for a scenario.
- describe the use of virtual LANs (VLAN) to allow multiple subnets to be connected with a single port-based switch. Be sure to include broadcast domain separation, flexibility for re-assigning hosts within the VLAN, connection mechanisms for when the same VLAN is connected across switches.
- describe how link virtualization allows links to be more than just a simple "channel connecting adjacent nodes"
- diagram the encapsulation of messages inside segments inside packets inside frames. Ensure you can handle cases such as ICMP and ARP.
- describe MPLS, including advantages, labeled frame formats (why is the label between link-layer and IP headers?), router operations. Be able to describe what an MPLS forwarding table might look like, given some MPLS enabled network scenario.
- explain the challenges of a wireless subnet, including those caused by range limits, mobility, receiver shutdown, noise, multi-path, hidden terminal, and exposed terminal problems.
- describe the CSMA/CA algorithm and how it helps overcomes some of the wireless challenges.
- describe the use of channel reservations to avoid collisions.
- explain some features of the 802.11 standard (do not memorize features of the variants). Such features include operating modes, security, frame format, power management and rate adaptation.
- describe the structure of a software-defined network, including flow-tables (and actions therein), controllers (and actions therein), and domains.
- prove you did the readings by answering general, large-concept questions about them.