• Do not open the exam until you are told to begin.
• Write your name **legibly** on every page.
• You have 80 minutes to complete the exam.
• There is no leaving the room while taking the exam. If you think you might need to leave the room during the exam, you must do so *before* starting the exam.
• No electronic devices are allowed. You can leave numeric answers as fractions in the form a/b.
• The exam has 6 questions, 72 points total.
• Not all points are created equal. Go for the easy points first!
• Make sure you have all 6 pages, including the cover page, of the exam before you hand it in.
• You may only use a pencil or a black- or blue-colored pen.
• The Rutgers policy on Academic Integrity applies to this exam.
• Show ALL work.
1. [10 points]
Name 2 differences between TCP and UDP and situation for each where UDP would be more desirable.

*Application-level control of data transmission* - the application designer can use UDP to guarantee when a packet will be sent since UDP traffic does not utilize any congestion control.
*No connection establishment* - with UDP traffic, there is no need to engage in handshaking or any other connection setup since the packets are self-contained. This also reduces the latency of UDP transmissions.
*No connection state* - because less information is needed to keep track of UDP "connections" than TCP connections, a server using a UDP-based protocol can typically support more simultaneous "connections" than one using a TCP-based protocol.
*Smaller packet overhead* - UDP packets contain only 8 bytes of overhead compared to 20 bytes for TCP.

2. [10 points]
List two types of network architectures and the defining characteristics of each.

A packet-switched network is defined by the transmission of discrete, encapsulated packets (or messages) across the network. A packet-switched network may or may not guarantee that two packets traveling from the same source to the same destination will travel the same route. These networks are usually used for data transmission.

A circuit-switched network establishes each connection across a physical or virtual circuit. This circuit is dedicated solely to the transmission of information directly between the hosts on either end. Circuits typically require set-up time and circuit-switched networks are usually used in telephony.
3. [7 points]
Assume that we want to transmit 300KB of data 4km across a link with a 1Mbps pipe with a propagation delay factor of 30μs/km. Also assume that each host requires 100 μs to execute the protocol. How long will it take to transmit all data?

We want to send 300,000B of data (= 2,400,000b) across a 1,000,000 bps link. Transmission delay, then, is 2.4s (2.4b/1bps).
Propagation delay is 30μs/km * 4km = 120μs.
Protocol delay is 100μs/host * 2 hosts = 200μs.
Total delay = 2.4s + 0.00012s + 0.0002s = 2.40032s
4. [15 points]
Answer the following questions and justify your answer in 1 or 2 sentences:

1. What is the main advantage of persistent connections in HTTP? (4 points)

   The main advantage of persistent connections is that they allow a client to request more than one object without having to reestablish a connection.

2. What is the main advantage of pipelining within a persistent HTTP connection? (4 points)

   The main advantage of pipelining within a persistent HTTP connection is that the client can request multiple objects from the server without having to wait for responses from previous requests.

3. What is the main advantage of parallel connections in HTTP? (4 points)

   The main advantage of parallel connections is the ability to request multiple objects simultaneously.

4. If we want to retrieve a webpage with a large number of small embedded objects, what would be the best, in terms of RTT latency, type of connection to use? (3 points)

   The best method would be to use persistent connections with pipelining. This would result in the lowest overall latency because after the initial object has been returned, the embedded objects can all be requested and received with only 1 RTT of additional latency.
5. [10 points]
Suppose a single bottleneck link with 4Mbps of bandwidth connects a University LAN to the Internet. The average size of objects by the University's LAN is 90KB and that the average request rate is 3 requests per second. Assume also that the router on the Internet side of the link takes 3 seconds to return requests forwarded to it.

Model the total average response time as the sum of the average access delay (between the LAN router and the Internet router) and the average Internet delay. For the average access delay, use $\Delta/(1-\beta \Delta)$, where $\Delta$ is the average time required to send an object over the access link and $\beta$ is the arrival rate of objects to the access link. Find the total average response time.

Average access delay:
Transmission delay – we want to send 90,000B (=720,000b) across a 4,000,000bps link.
$72/400 = 18/100 = .18s = \Delta$

$AAD = 0.18s/[1-(3\text{req/s})(0.18s/\text{req})] = 0.18s/[1-0.54] = 0.18s/0.46$
$= 18/46 s$
So average response time = $18/46s + 3 s = 3.391s$ (approx)
6. [20 points]
Assume you have a network where packets can never get corrupted, only lost. Design a sender-receiver pair for this scenario and illustrate your design with a pair of Finite State Machines. Give a brief informal argument about the correctness of your design. (Make your design as simple as possible, but make sure all messages will eventually arrive, and that they will arrive in order.)