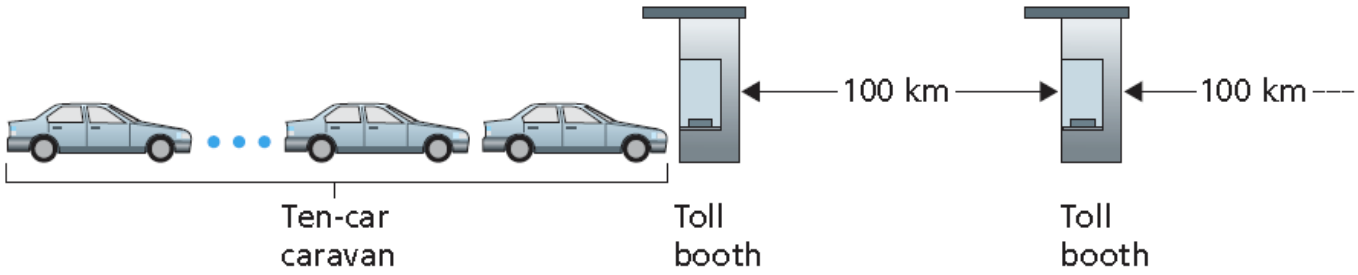
Answer the following questions and **explain** your answer in **English**.

Submit **PDF** on KLMS by Sep 23th 11:59PM

[Problem1] Consider a highway that has a tollbooth every 100 kilometers, as shown below. You can think of the highway segments between tollbooths as links and the tollbooths as routers. Suppose that cars travel (that is, propagate) on the highway at a rate of 50 km/hour (that is, when a car leaves a tollbooth, it instantaneously accelerates to 50 km/hour and maintains that speed between tollbooths). Suppose next that 20 cars, traveling together as a caravan, follow each other in a fixed order. You can think of each car as a bit and the caravan as a packet. Also suppose that each tollbooth services (that is, transmits) a car at a rate of one car per 15 seconds, and that it is late at night so that the caravan's cars are the only cars on the highway. Finally, suppose that whenever the first car of the caravan arrives at a tollbooth, it waits at the entrance until the other nineteen cars have arrived and lined up behind it. (Thus the entire caravan must be stored at the tollbooth before it can begin to be forwarded.)



A. Suppose the caravan travels 300 km, beginning in front of one tollbooth, passing through a second and third tollbooth, and finishing just after a fourth tollbooth. What is the end-to-end delay?

B. Repeat (a), now assuming that there are sixteen cars in the caravan instead of twenty.

[Problem2] Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

A. Express the propagation delay, d_{prop}, in terms of m and s.

B. Determine the transmission time of the packet, d_{trans}, in terms of L and R.

C. Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

D. Suppose Host A begins to transmit the packet at time t = 0. At time t = d_{trans}, where is the last bit of the packet?

E. Suppose d_{prop}, is greater than d_{trans}. At time t = d_{trans}, where is the first bit of the packet?

F. Suppose d_{prop} is less than d_{trans}. At time t = d_{trans}, where is the first bit of the packet?

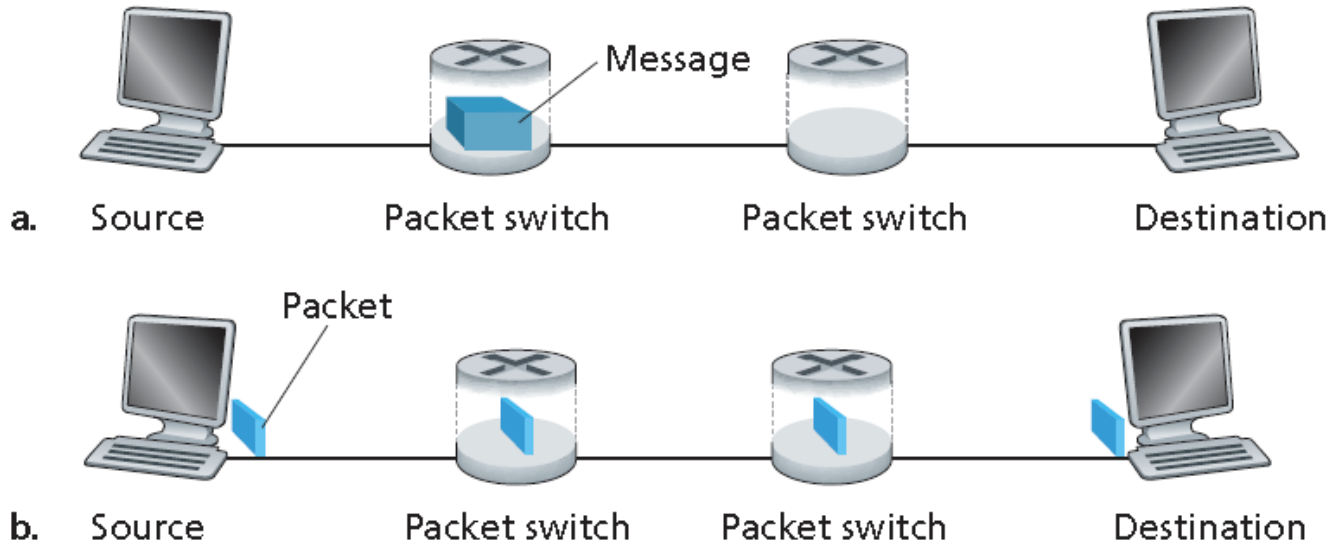
G. Suppose s = 2×10^8, L = 150 bits, and R = 60 kbps. Find the distance m so that d_{prop} equals d_{trans}.

[Problem3] Suppose users share a 6 Mbps link. Also suppose each user requires 200 kbps when transmitting, but each user transmits only 5 percent of the time.

A. When circuit switching is used, how many users can be supported?

B. Suppose there are 100 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (Hint: Use the binomial distribution.)

[Problem4] In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as message segmentation. Below image illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is 12×10^6 bits long that is to be sent from source to destination in below image. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.



♦ End-to-end message transport: (a) without message segmentation; (b) with message segmentation

A. Consider sending the message from source to destination without message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

B. Now suppose that the message is segmented into 3000 packets, with each packet being 4,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

C. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (A) and comment.

[Problem5] The text below shows the reply sent from the server in response to the HTTP GET message in the question above. Answer the following questions, indicating where in the message below you find the answer.

```
HTTP/1.1 200 OK<cr><lf>Date: Tue, 07 Mar 2008
12:39:45GMT<cr><lf>Server: Apache/2.0.52 (Fedora)
<cr><lf>Last-Modified: Sat, 10 Dec2005 18:27:46
GMT<cr><lf>ETag: "526c3-f22-a88a4c80"<cr><lf>Accept-
Ranges: bytes<cr><lf>Content-Length: 3874<cr><lf>
Keep-Alive: timeout=max=100<cr><lf>Connection:
Keep-Alive<cr><lf>Content-Type: text/html; charset=
ISO-8859-1<cr><lf><cr><lf><!doctype html public "-
//w3c//dtd html 4.0 transitional//en"><lf><html><lf>
<head><lf> <meta http-equiv="Content-Type"
content="text/html; charset=iso-8859-1"><lf> <meta
name="GENERATOR" content="Mozilla/4.79 [en] (Windows NT
5.0; U) Netscape]"><lf> <title>CMPSCI 453 / 591 /
NTU-ST550A Spring 2005 homepage</title><lf></head><lf>
<much more document text following here (not shown)>
```

A. Was the server able to successfully find the document or not? What time was the document reply provided?

B. When was the document last modified?

C. How many bytes are there in the document being returned?

D. What are the first 5 bytes of the document being returned? Did the server agree to a persistent connection?