CS 372 Introduction to Computer Networks
Self-Check Exercises: Lecture 4 **Solutions**

1) What is an access network?
A network that allows a host to connect to the internet

2) **Throughput** is the rate at which bits are actually transferred between sender/receiver.

3) Describe the sources of nodal delay in packet-switched networks.
Processing delay: Time spent processing header information, checking bit errors, and deciding outport link
Queueing delay: Time waiting for the transmission medium
Transmisison delay: Time spent being placed on the transmission medium, limited by the transmission protocol.
Propagation delay: Time spent traveling on the physical medium

4) What is the equation for end-to-end delay?
$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$

5) Consider two hosts (A and B) connected by a single link with transmission rate ***R*** bps. The hosts are separated physically by ***d*** meters along a cable for which the speed of propagation is ***s*** meters per second. Host A sends a packet of length ***L*** bits to host B
   a. Show the propagation delay d_{prop} in terms of ***d*** and ***s*****:** d_{prop} **= d/s**
   b. Show the transmission delay d_{trans} in terms of ***L*** and ***R*****:** d_{trans} **= L/R**
   c. Suppose Host A begins to transmit at time t = 0. At time t = d_{trans} where is the last bit of the packet?
   Just leaving the sending host (Host A)
   d. Suppose that $d_{prop} > d_{trans}$. At time t = d_{trans} , where is the first bit of the packet?
   Somewhere in the link between Host A and Host B
   e. Suppose that $d_{prop} < d_{trans}$. At time t = d_{trans} , where is the first bit of the packet?
   At the receiving host (Host B)
   f. Let s = 2.5×10^8 m/s, L = 120 bits, R = 56 Kbps. Find ***d*** such that $d_{prop} = d_{trans}$.
   Set **d/s = L/R**
   120 / 56,000 = **d** / 250,000,000
   d = 250,000,000 * 120 / 56,000 = 535,714.28 m ≈ 535.7 km

6) Suppose that there are *N* packets in a router's queue. Given a constant packet length of *L*, and a constant transmission rate *R*, what is the average queuing delay for the *N* packets?

1st packet delay =0; 2nd packet delay=L/R; 3rd packet delay = 2L/R; etc

So, average delay for N packets is

$$\frac{\left[\frac{L}{R}+\frac{2L}{R}+\dots+\frac{(N-1)L}{R}\right]}{N} = \frac{N(N-1)L}{2NR} = \frac{L(N-1)}{2R} \text{ seconds}$$

Explanation:

To simplify $\left[\frac{L}{R}+\frac{2L}{R}+\ \dots\ +\frac{(N-1)L}{R}\right]/N$, use the summation formula $\sum_{i=1}^{p} i = \frac{p(p+1)}{2}$, or solve algebraically as follows:

Combine the first term and last term of the numerator.

$$L/R + (N-1)L/R = \boldsymbol{NL/R}$$

Then combine the second term and the next-last term.

$$2L/R + (N-2)L/R = \boldsymbol{NL/R}$$

etc. $3L/R + (N-3)L/R = \boldsymbol{NL/R}$, $4L/R + (N-4)L/R = \boldsymbol{NL/R}$

So we end up with $(N-1)/2$ pairs that add up to $\boldsymbol{NL/R}$, i.e., $\frac{\boldsymbol{N-1}}{\boldsymbol{2}} * \frac{\boldsymbol{NL}}{\boldsymbol{R}}$

and $\frac{\left(\frac{N-1}{2}\right)\left(\frac{NL}{R}\right)}{N} = \frac{N(N-1)L}{2NR} = \frac{L(N-1)}{2R}$

Note: depending on whether *N* is even or odd, we might have one term that doesn't have another term with which to be combined, but this is handled correctly because $(N-1)/2$ will have a remainder of 1 when *N* is even.