Trivia Question (1 extra credit point)

0. (a) What is the capital of Libya?

-OR-

(b) What city is hosting this year’s NCAA men’s basketball Final Four games?
1a. What is a network protocol?

(3 pts.)

b. Explain the differences between the OSI Reference Model and the TCP/IP Internet stack.

(3 pts.)

2a. Explain the difference between channel utilization and channel efficiency.

(2 pts.)

b. What is the difference between end-to-end packet latency and end-to-end packet delay?

(2 pts.)

3. Provide pseudo-code (in Tanenbaum style) for a one-directional flow of data from a sending node to a receiving node in a one-bit sliding window protocol where the receiver sends an ACK when a frame is transmitted correctly and a NAK when a frame is received with errors detected.

Sender                             Receiver
4. Explain the **HDLC** scheme for **framing** and **byte stuffing**.

5a. Why is **error correction** not normally used at the data link layer?

5b. What is used instead?

6. Give the algorithm that the sender uses to prepare and send a frame for transmission that includes a **CRC** field.

7. Assume that the voltage level at time $t = 0$ is **low**, fill in the diagram below to show the **Differential Manchester encoding** for the bit stream 00010110 traveling to the left.

```
|   |   |   |   |   |   |   |   |
```

bit edge ($t=0$)
(3 pts.) 8. A **V.34 modem** runs at **2400 baud** to achieve **33,600 bps**. Based on **Nyquist’s theorem**, how many **levels** does this modem use to achieve this data rate?

(2 pts.) 9. Explain the difference between **amplitude modulation** and **phase modulation**.

(5 pts.) 10. Draw a diagram and explain how a **T1 carrier** works?

(3 pts.) 11. How does **delta modulation** work and where it would be used?

(3 pts.) 12. Briefly explain the components of the **HFC** architecture.
Two nodes A and B are 60 km apart at opposite ends of a 100 Mbps optical fiber link. Assume the speed of light is $3 \times 10^8$ meters/sec. Assume node A has a 51,231 byte image stored in memory to send to B.

A and B share a three-layer ‘home brew’ network where:

Network layer **packets** have the following format:

<table>
<thead>
<tr>
<th>Header</th>
<th>Payload</th>
<th>Trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 bytes</td>
<td>4-256 bytes</td>
<td>8 bytes</td>
</tr>
</tbody>
</table>

**DATA frames** have the following format:

<table>
<thead>
<tr>
<th>Header</th>
<th>Payload</th>
<th>Trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 bytes</td>
<td>75-1200 bytes</td>
<td>20 bytes</td>
</tr>
</tbody>
</table>

**ACK frames** have the following format:

<table>
<thead>
<tr>
<th>Header</th>
<th>Payload</th>
<th>Trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 bytes</td>
<td>75 bytes</td>
<td>20 bytes</td>
</tr>
</tbody>
</table>

Processing time for A or B to prepare to send any frame is 4 microseconds.
Processing time for A or B to receive any frame is 1 microsecond.

The Data Link layer of the ‘home-brew’ network uses a simple STOP-and-WAIT protocol and for channel efficiency it tries to combine multiple packets into a single frame prior to transmission.

How long does it take A to successfully send the image to B under the best of circumstances (i.e., the channel is error-free)? (Show ALL calculations to get full or partial credit!)