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**DEPARTMENT OF ELECTRONIC AND COMPUTER ENGINEERING**
**THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY**

# ELEC1200 Final Exam

**Date: 12 December 2019 (Thursday)**

**Time: 09:30 – 11:30 (2 hours)**

**Upload Deadline: 11:35 AM on 12 December 2019 (Thursday)**

***Notes and instructions:***

1. Exam paper will be uploaded and released at 09:25 am on 12th December to Canvas.
2. You have two hours to complete this exam plus an additional 10 min for downloading, scanning and uploading.
3. You can complete the exam by either 1) provide answers on your own paper or 2) print the exam out and complete the answers directly on it or 3) annotate answers directly on the downloaded file.
4. Scan and upload your answers to Canvas before the deadline. Please allow 5 minutes for uploading and follow these instructions:

    - On Canvas, go to 'Assignments', click the 'Final Exam', click 'Submit Assignment' and then click 'Choose File', choose the correct file from your computer.
    - Then, click the 'Submit Assignment' button.
    - Make sure that you can view the 'Submission Details'.

5. Please use our backup email (eecupid@ust.hk) just in case you have trouble in submitting the answers through Canvas.
6. There are 10 questions with 10 marks each.
7. You may use your lecture notes and calculator during the exam
8. No hardcopy paper submission.
9. No late submission will be accepted (ZERO marks!)
10. You may call us at 2358 8564 (Cupid) or 2358 7044 (Prof. Murch) or email us if you have a question during the exam.

**Answers should show clear steps**
**No/wrong units will result with zero marks!**

*Declaration of Academic Integrity*

*I confirm that I have answered the questions using only materials specifically approved for use in this examination, that all the answers are my own work, and that I have not received any assistance during the examination.*

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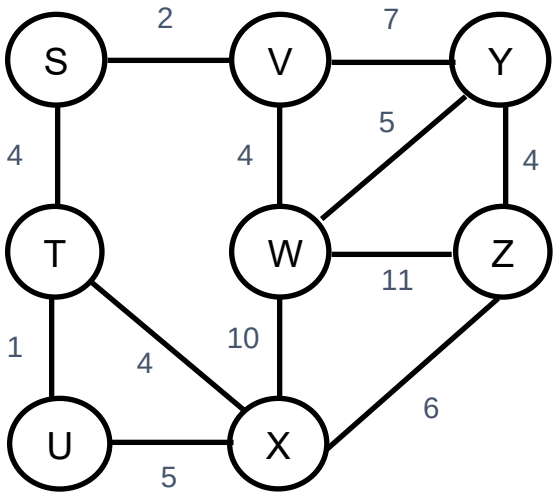
## Question 1 [10]

Consider the following network with the indicated link costs and **S** is the source node.




Use Dijkstra's shortest-path algorithm to obtain the followings (remember to show all the steps):

(a) [3.5] The shortest path from S to all other nodes.

(Copy the table below into your answer sheets and complete it.)

| Step | N | D(U), P(U) | D(X), P(X) | D(Z), P(Z) | D(W), P(W) | D(T), P(T) | D(V), P(V) | D(Y), P(Y) |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
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(b) [3] The shortest path tree from S.

(c) [3.5] The Forwarding Table for S.

(Copy the table below into your answer sheets and complete it.)

| Destination | Link |
|---|---|
| T | |
| U | |
| V | |
| W | |
| X | |
| Y | |
| Z | |

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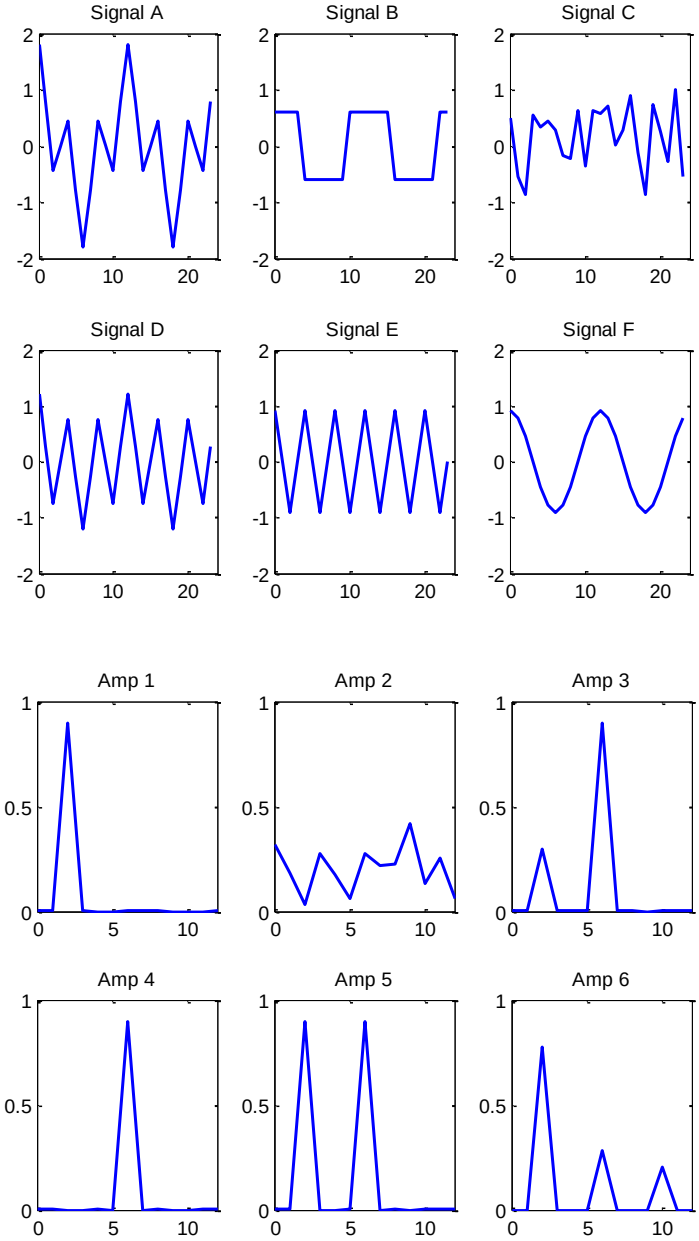
## Question 2 [10]

Part I: [6] Each signal shown below (labelled Signal A to F), consists of 24 samples. Match them with the corresponding Amplitude Spectrum (labelled Amp 1 - 6). In the signal plots, the horizontal axis is sample index (n). In the Amplitude Spectrum plots, the horizontal axis is frequency index (k).




(Copy the table below into your answer sheets and complete it.)

| Signal | Amplitude Spectrum |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |
| F | |

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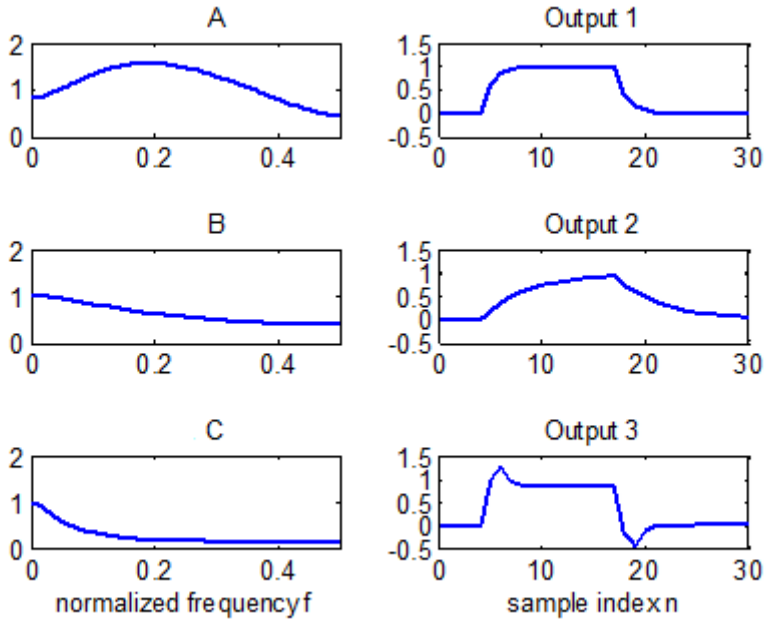
Part II: [3] Suppose that the waveform $x(n) = u(n-5) - u(n-18)$ where $u(n)$ is the unit step function, is passed to three linear time invariant channels.

These three channels (labelled A, B and C below) whose frequency responses as a function of normalized frequency $f$ are shown on the left. For each channel, select its corresponding output on the right (Output 1, 2, or 3).




Copy the table below into your answer sheets and complete it.

| Filter | Output |
|---|---|
| A | |
| B | |
| C | |

(b) [1] Which of the channels (labeled A, B and C) could be classified as low pass filters?

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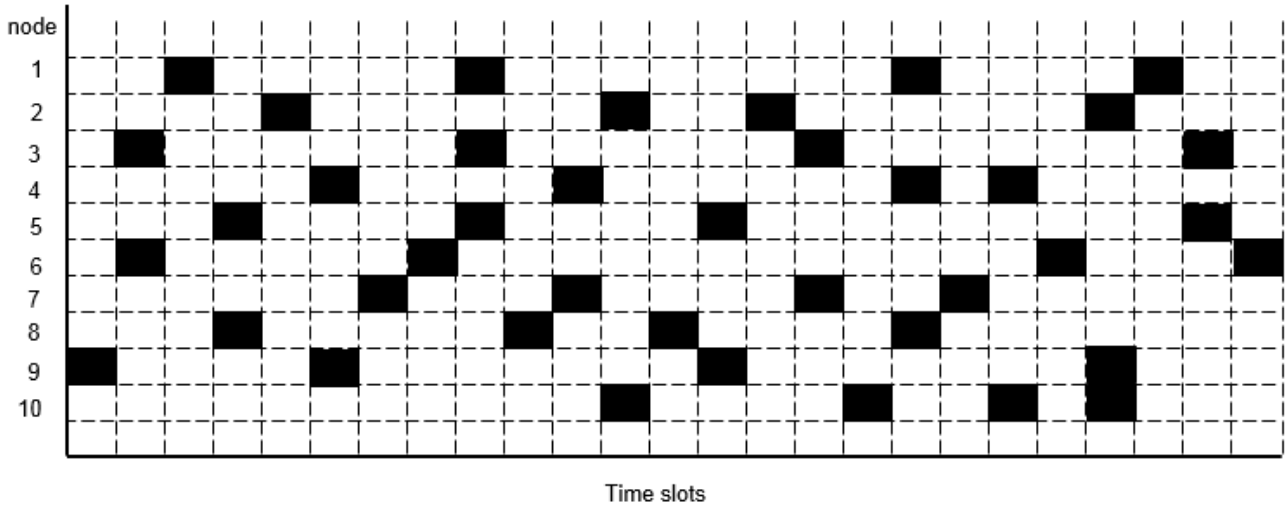
**Question 3 [10]**

Part I: Consider a Slotted Aloha random multiple access protocol where there are 10 nodes that send frames through the network of a shared channel as shown below. [6]




(a) [2] Calculate the efficiency.

(b) [2] Calculate the throughput if each time slot is 20 ms long.

(c) [2] Estimate the probability of a node to transmit a frame in a time slot.

Part II: Computers X and Y are sharing a wireless network and the network runs the Slotted Aloha protocol with equal-sized packets. You want Y to get twice the throughput over the wireless network as X whenever both nodes are backlogged. You configure X to send packets with probability p.

[4] What should you set the transmission probability of Y to, in order to achieve your throughput goal? Show all working.

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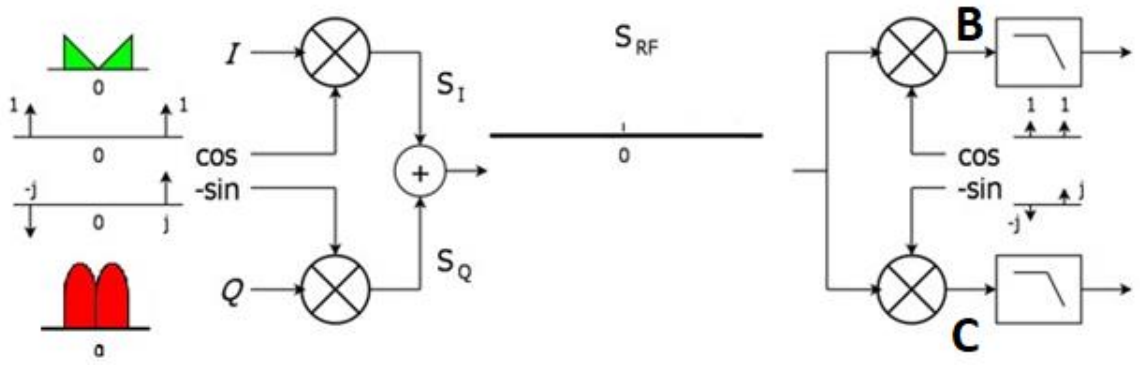
**Question 4 [10]**

As illustrated in the figure below, baseband signals, which have in-phase component I(t) and quadrature component Q(t), are input to an ideal IQ-modulator generating system with carrier frequency $f_c$.




(a) [2] Sketch the spectrum of the modulated in-phase component I(t) (signal $S_I$).

(b) [2] Sketch the spectrum of the modulated quadrature component Q(t) (signal $S_Q$).

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(c) [2] Sketch the spectrum of signals at point B, right after we demodulate the combined signal using a cosine.

(d) [2] Sketch the spectrum of signals at point C, right after we demodulate the combined signal using a sine.

(e) [2] What will be the output if the I and Q channels are swapped during demodulation?

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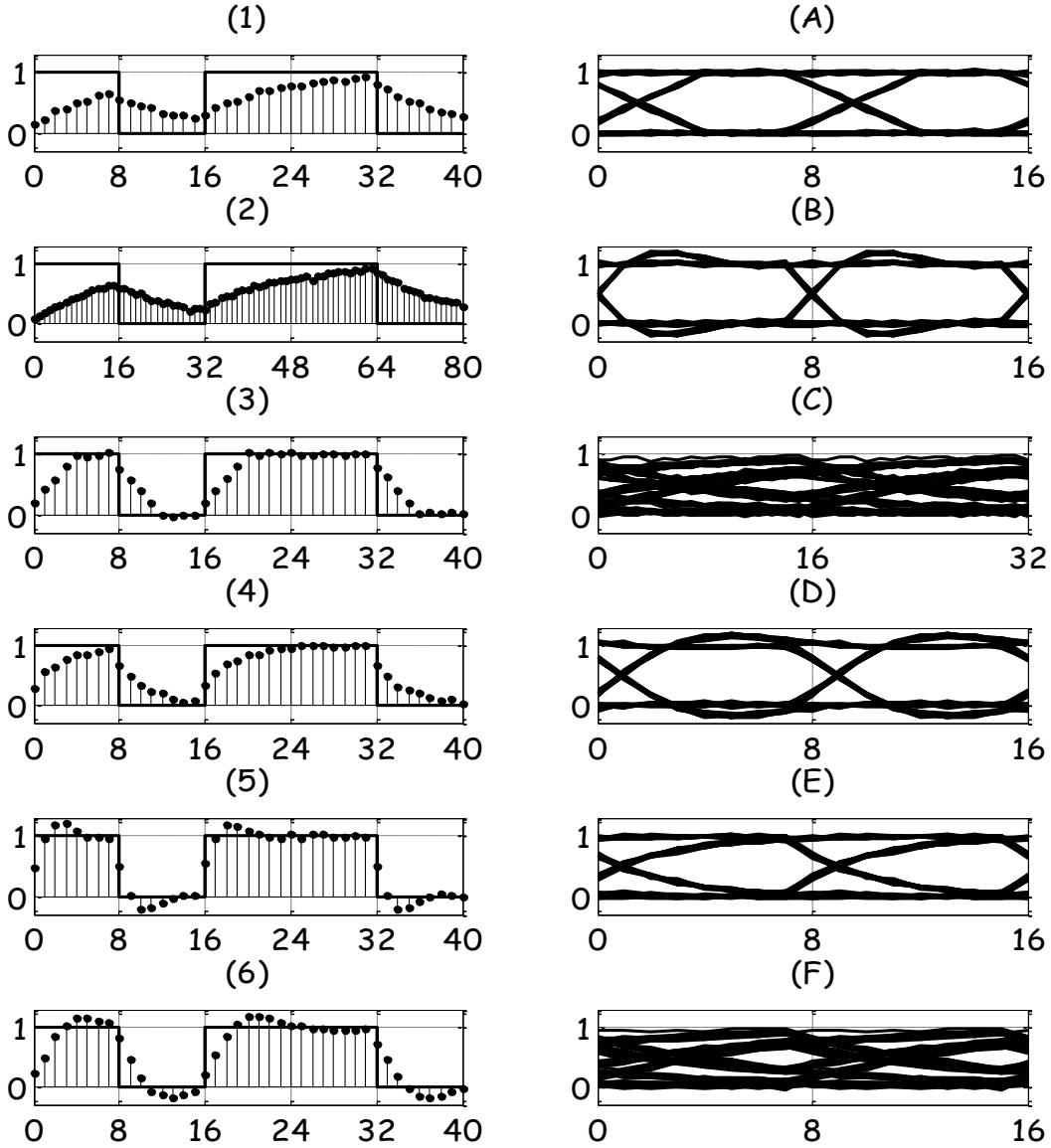
**Question 5 [10]**

Part I: [6] The first column shows the output (circles) of different communication channels to the first five bits of a random bit input waveform (solid line). The second column shows the eye diagram resulting from overlaying plots of 2*SPB+1 samples for the same channels but in random order. Match each input/output pair to the correct eye diagram.




Match numbers on the left with letters of the corresponding eye diagram on the right. (Copy the table below into your answer sheets and complete it.)

| | | | | |
|---|---|---|---|---|
| 1 | | | 4 | |
| 2 | | | 5 | |
| 3 | | | 6 | |

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Part II: [4] Suppose that a channel has the following step response

$$s[n] = k\,(1 - 0.8^{n+1})\,u[n]$$

where $u[n]$ is the unit step function. In order to help identify a suitable threshold, a training sequence consisting of a pulse of some samples of 1's is transmitted. Find the minimum pulse width of the training sequence such that the maximum value of the channel output is greater than $0.9k$.

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**Question 6 [10]**

Consider the following applications:

| Application | Application Layer Protocol | Transport Layer Protocol |
|---|---|---|
| (1) Email | (i) VoIP | (a) TCP |
| (2) Web | (ii) SMTP | (b) UDP |
| (3) File Transfer | (iii) SSH | |
| (4) Internet telephony | (iv) HTTP | |
| (5) Remote login | (v) FTP | |

(a) [5] Match each of the following Applications with the corresponding application layer protocol and transport layer protocol.
(Copy the table below into your answer sheets and complete it.)

| **Application** | **Application Layer Protocol** | **Transport Layer Protocol** |
|---|---|---|
| (1) Email | | |
| (2) Web | | |
| (3) File Transfer | | |
| (4) Internet Telephony | | |
| (5) Remote Login | | |

(b) [5] Mark them as being data loss tolerant (indicate No loss or loss-tolerant) and time sensitive (indicate No or Yes) by copying the table below into your answer sheets.

| **Application** | **Data Loss Tolerant [No loss/loss-tolerant]** | **Time sensitive [yes/no]** |
|---|---|---|
| (1) Email | | |
| (2) Web | | |
| (3) File Transfer | | |
| (4) Internet Telephony | | |
| (5) Remote Login | | |

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**Question 7 [10]**

Consider the continuous-time signal:

$$x(t) = 4\cos(2\pi(100)t) + 6\cos(2\pi(500)t) + 2\cos(2\pi(2000)t)$$

where $t$ is measured in seconds.

Suppose $x(t)$ is sampled starting at t=0 at a sampling frequency of $F_s$ = 10 kHz. Let $x(n)$ be the sampled data waveform, which can be expressed as:

$$x(n) = A_o + \sum_{k=1}^{50} A_k \cos(2\pi f_k n) \qquad \text{for } n = 0, \ldots, 99$$

where $f_k = \frac{k}{N}$ and $N = 100$.

$f_k$ is the normalized frequency in units of cycles per sample.

(a) [1] For how long was the continuous time waveform sampled?

(b) [3] How many non-zero normalized frequency components are there? Write down the values of the non-zero normalized frequencies.

(c) [6] Sketch the amplitude spectrum $A_k$ versus $k$. Clearly mark the value for each $A_k$ and $k$.

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**Question 8 [10]**

Assume that we have x[n] = [0111100000111011] as the input signal to a linear time-invariant channel with SPB = 1. The step response of the channel is s[n].

(a) [2] Write x[n] in terms of unit step functions.

(b) [2] Write the output of the channel y[n] in terms of the channel step response s[n] for the input x[n] in part (a).

(c) [6] What are the **values of the output y[n] for n = 0 to 16**, when the step response s[n] is:

$$s[n] = \begin{cases} 0.25, & n = 0 \\ 0.5, & n = 1 \\ 0.75, & n = 2 \\ 1, & n > 2 \end{cases}$$

(Copy the table below into your answer sheets and complete it.)

| n | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| y[n] | | | | | | | | | | | | | | | | | |

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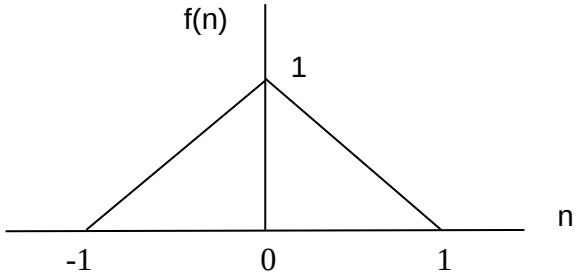
**Question 9 [10]**

Suppose that the output of a communication system can be modeled as:

$$y = r + n \qquad \text{where} \quad r = \begin{cases} 0.7 & \text{if bit '1' is transmitted} \\ 0 & \text{if bit '0' is transmitted} \end{cases}$$

where the noise $n$ has the following probability density function (pdf).




Answer the following questions assuming that '0' and '1' bits are equally likely to be transmitted and that the optimal threshold is used for decoding '0' and '1' bits from the received output**.**

**(Clearly mark all the values on the sketches!)**

(a) [2] Sketch the pdf of y when bit '1' is transmitted.

(b) [2] Sketch the pdf of y when bit '0' is transmitted.

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(c) [1] Find the optimal threshold.

(d) [2] Calculate the error probability (BER).

Suppose that the noiseless signal *r* has changed. Now the signal levels corresponding to the “0” and “1” bits are:

$$r = \begin{cases} 1.4 & \text{if bit "1" is transmitted} \\ 1 & \text{if bit "0" is transmitted} \end{cases}$$

Find the numerical values in the following parts.

(e) [2] The BER if the threshold value is the same as that in c).

(f) [1] The new optimal value of the threshold.

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**Question 10 [10]**

Suppose sender A and a receiver B communicate using the stop-and-wait protocol. There are 4 links on the path between A and B, each with a data rate of 125 Mbps. The size of each TCP packet is 500 kbits long.

(a) [2] What is the transmission time for a TCP packet on one link between A and B?

(b) [2] What is the round trip time (RTT) between A and B?

(c) [2] If there are no packet losses, then what is the throughput of this connection?

(d) [2] Each link has a packet loss probability of 0.2, with packets being lost independently. What is the probability that a packet sent by A will reach B?

(e) [2] What is the expected number of transmission of a packet before A can send the next packet in sequence?

-------- End of Exam --------