**Exam Instructions**:

- This exam contains 7 pages (including this cover page) and 40 questions.

- The use of any electronic device is not allowed during the exam.

- All answers must be written in the designated answer table.

- Use the following information to help with unit conversions:
    - 1 second = 1000 milliseconds (msec) = 1000000 microseconds.
    - 1 Mb = 1000 Kb = 1000000 bits.

## Answer Table

| Q | Answer | Q | Answer |
|---|--------|---|--------|
| 1. | (A) (B) (C) (D) (E) | 21. | (A) (B) (C) (D) (E) |
| 2. | (A) (B) (C) (D) (E) | 22. | (A) (B) (C) (D) (E) |
| 3. | (A) (B) (C) (D) (E) | 23. | (A) (B) (C) (D) (E) |
| 4. | (A) (B) (C) (D) (E) | 24. | (A) (B) (C) (D) (E) |
| 5. | (A) (B) (C) (D) (E) | 25. | (A) (B) (C) (D) (E) |
| 6. | (A) (B) (C) (D) (E) | 26. | (A) (B) (C) (D) (E) |
| 7. | (A) (B) (C) (D) (E) | 27. | (A) (B) (C) (D) (E) |
| 8. | (A) (B) (C) (D) (E) | 28. | (A) (B) (C) (D) (E) |
| 9. | (A) (B) (C) (D) (E) | 29. | (A) (B) (C) (D) (E) |
| 10. | (A) (B) (C) (D) (E) | 30. | (A) (B) (C) (D) (E) |
| 11. | (A) (B) (C) (D) (E) | 31. | (A) (B) (C) (D) (E) |
| 12. | (A) (B) (C) (D) (E) | 32. | (A) (B) (C) (D) (E) |
| 13. | (A) (B) (C) (D) (E) | 33. | (A) (B) (C) (D) (E) |
| 14. | (A) (B) (C) (D) (E) | 34. | (A) (B) (C) (D) (E) |
| 15. | (A) (B) (C) (D) (E) | 35. | (A) (B) (C) (D) (E) |
| 16. | (A) (B) (C) (D) (E) | 36. | (A) (B) (C) (D) (E) |
| 17. | (A) (B) (C) (D) (E) | 37. | (A) (B) (C) (D) (E) |
| 18. | (A) (B) (C) (D) (E) | 38. | (A) (B) (C) (D) (E) |
| 19. | (A) (B) (C) (D) (E) | 39. | (A) (B) (C) (D) (E) |
| 20. | (A) (B) (C) (D) (E) | 40. | (A) (B) (C) (D) (E) |

1. Which of the following physical layer technologies has the highest transmission rate and lowest bit error rate in practice?

   (A) Coaxial cable. (B) Satellite channel. (C) **Fiber optic cable.** (D) Twisted pair. (E) All of the mentioned.

2. Guided media examples include:

   (A) Copper. (B) Fiber. (C) Coaxial. (D) **All of the mentioned.** (E) None of the mentioned.

3. Packet forwarding function is responsible for:

   (A) Getting a packet from one host to another over the network.

   (B) **Getting a packet from a router's input link to the appropriate output link.**

   (C) Delivering a packet without errors.

   (D) Retransmitting a packet when errors occur.                 (E) All of the mentioned.

4. One of the causes of packet loss is (select the best option):

   (A) A long path from the source to the destination.          (B) A large packet size.
   (C) A low bandwidth link.   (D) **Router's port buffer overflow.**   (E) None of the mentioned.

5. One of the main jobs of an Internet Exchange Point (IXP) is:

   (A) Providing Internet connectivity to end users by a direct connection.

   (B) **Providing a point of network traffic exchange for multiple ISPs.**

   (C) Connecting end users of the same access network to each other.

   (D) Forwarding packets from one device to another in a home network.

   (E) None of the mentioned.

6. Out of the following points, which one **does not** have an impact on propagation delay?

   (A) Physical link length. (B) Propagation speed.   (C) **Packet length.**   (D) A and B. (E) B and C.

7. What guarantee does UDP offer?

   (A) Reliability.          (B) Congestion and flow control.          (C) Security.
   (D) Minimum throughput.              (E) **None of the mentioned.**

8. What guarantee does TCP offer?

   (A) **Reliability.**   (B) Low delay.   (C) Security.   (D) Minimum throughput.   (E) A and D.

9. One of the main reasons of using a web cache is:

   (A) Eliminate the need to connect to origin servers.          (B) Store all objects in the Internet.
   (C) **Reduce response time for clients.**   (D) Reduce requested object size.   (E) All of the mentioned.

10. When traffic intensity of an access network link gets close to 1, the best thing we can do is:

    (A) Install a web cache close to the origin server.   (B) Buy a faster access link.   (C) **Install a web cache close to the client's access network.**   (D) A and B.   (E) All of the mentioned.

11. It is not practical to install only one DNS server for the whole Internet for the following reason(s):

(A) It does not scale.   (B) It is a single point of failure.   (C) It will have a high maintenance cost.

(D) A and B.            **(E) All of the mentioned.**

12. Which of the following DNS record types is used to retrieve the authoritative name server of a given domain?

(A) Type A.   (B) Type CNAME.   **(C) Type NS.**   (D) Type MX.   (E) None of the mentioned.

13. Which of the characteristics below best describes the technique of packet switching?

(A) Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM) are two approaches for implementing this technique.

**(B) Resources are used on demand, not reserved in advance.**

(C) Reserves resources needed for a connection between source and destination.

(D) This technique is no longer used in the Internet.

(E) None of the mentioned.

14. Which of the characteristics below are associated with the technique of circuit switching?

(A) Data may be queued before being transmitted due to other user's data that's also queueing for transmission.

(B) Resources are used on demand, not reserved in advance.

**(C) Reserves resources needed for a connection between source and destination.**

(D) This technique is used in the Internet.

(E) None of the mentioned.

15. Which CDN approach is used to deploy CDN servers in as many access networks as possible?

(A) Bring home.    **(B) Enter deep.**    (C) DASH.    (D) DNS.    (E) What is CDN?

16. Assume the RTT of the first 3 TCP segments of a given connection is 200ms for each segment, and assume the initial EstimatedRTT is set to 1 second (1000ms). Then, after taking these 3 segments into account:

(A) EstimatedRTT will stay the same (1 second).      (B) EstimatedRTT will be > 1 second.

(C) EstimatedRTT will be 0.    **(D) EstimatedRTT will be < 1 second.**    (E) None of the mentioned.

17. Which of these statements is true?

(A) The Internet protocol (IP) is reliable.      (B) UDP provides additional reliability on top of IP.

(C) TCP provides a minimum bandwidth guarantee.      (D) The HTTP protocol is stateful.

**(E) None of the mentioned.**

18. Which switching fabric design did first generation routers use?

(A) Switching via bus.    **(B) Switching via memory.**    (C) Switching via interconnection networks.    (D) Multi-stage switching fabric.    (E) None of the mentioned.

19. Which of these statements is true with regards to the different planes of the network layer?

(A) It consists of three planes: control, data, and switching.

(B) It consists of only one network plane.    (C) It consists of two planes: control and network.

**(D) It consists of two planes: control and data.**      (E) None of the mentioned.

20. Which of these statements is true with regards to per-router control plane in the traditional routing approach?

   (A) Only a subset of routers run individual routing algorithm components.

   (B) Only one router runs routing algorithm components.

   (C) **Each router runs individual routing algorithm components.**

   (D) Hosts run individual routing algorithm components.          (E) None of the mentioned.

21. Which of these statements is true with regards to the software-defined networking (SDN) approach?

   (A) Each router runs individual routing algorithm components.

   (B) Hosts run individual routing algorithm components.

   (C) Routers run software versions of routing algorithms.

   (D) **A remote controller computes packet routes and installs forwarding tables in routers.**

   (E) None of the mentioned.

22. Which of these statements is true with regards to Selective Repeat (SR)?

   (A) It is used by UDP to retransmit lost packets. (B) It is used to offer minimum delay guarantee.

   (C) All packets within the sender's window get retransmitted in the event of a timeout.

   (D) **Lost packets get retransmitted individually.**          (E) None of the mentioned.

23. Fast retransmit is a mechanism used for retransmitting:

   (A) Lost packets at fastest speed.     (B) **Lost packets before a timeout occurs.**     (C) Lost packets after a timeout occurs.     (D) Lost packets over a fast link.     (E) None of the mentioned.

24. Longest prefix match is used to:

   (A) Route a packet through the longest path possible.

   (B) Match a packet to the longest address prefix of a given source address.

   (C) **Match a packet to the longest address prefix of a given destination address.**

   (D) Drop a packet if it is too long.               (E) All of the mentioned.

25. Time spent waiting in packet buffers for link transmission is called:

   (A) Propagation delay.     (B) **Queuing delay.**     (C) Transmission delay.     (D) Processing delay.

   (E) None of the mentioned.

26. Time needed to perform an integrity check, lookup packet information in a local table and move the packet from an input link to an output link in a router:

   (A) Propagation delay.     (B) Queuing delay.     (C) Transmission delay.     (D) **Processing delay.**

   (E) None of the mentioned.

27. What is the maximum throughput achievable for UDP traffic between sender and receiver in the scenario shown below?
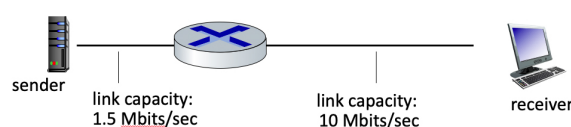


   (A) 0.75 Mbps.     (B) **1.5 Mbps.**     (C) 3 Mbps.     (D) 10 Mbps.     (E) 15 Mbps.

28. Select the correct order of protocol packet encapsulation that takes place when one host sends an application message over the Internet. Each is encapsulated by the one that follows it.

(A) message, datagram, segment, frame.      (B) message, segment, frame, datagram.

(C) message, frame, datagram, segment.      (D) message, datagram, frame, segment.

(E) **message, segment, datagram, frame.**

29. Which of the following datagram and segment header fields are used, when demultiplexing data up to a TCP socket?

(A) Destination IP address and port number only.

(B) **Source and destination IP addresses, and source and destination port numbers.**

(C) Destination port number only.   (D) Source port number only.   (E) None of the mentioned.

30. Which of the following datagram and segment header fields are used, when demultiplexing data up to a UDP socket?

(A) Destination IP address and port number only.

(B) Source and destination IP addresses, and source and destination port numbers.

(C) **Destination port number only.**      (D) Source port number only.      (E) None of the mentioned.

31. What is the Internet Checksum of these two sixteen bit numbers?
```
10110100 01000110
01001000 01101111
```
(A) `11111100 10110101`      (B) `00000011 01001010`      (C) **`01001010 00000011`**

(D) `10110101 11111100`      (E) `11111111 00000000`

32. Consider the network shown in the figure below, with three links, each with a transmission rate of 2 Mbps, and a propagation delay of 2 msec per link. Assume the length of a packet is 4000 bits.

What is the end-end delay of a packet from when it first begins transmission on link 1, until is it received in full by the server at the end of link 3? Assume store-and forward packet transmission.
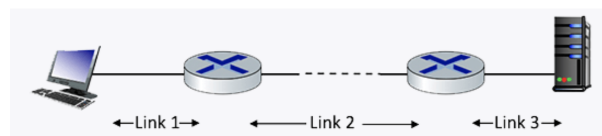


(A) 2 msec.      (B) 6 msec.      (C) 8 msec.      (D) **12 msec.**      (E) 15 msec.

**Note: the following figure (Figure-1) is used for the next 4 questions.**

Consider the figure below, where a TCP sender sends 8 TCP segments at $t = 1, 2, 3, 4, 5, 6, 7, 8$. Suppose the initial value of the sequence number is 0 and every segment sent to the receiver each contains 100 bytes. The delay between the sender and receiver is 5 time units, and so the first segment arrives at the receiver at $t = 6$. The ACKs sent by the receiver at $t = 6, 7, 8, 10, 11, 12$ are shown. The TCP segments (if any) sent by the sender at $t = 11, 13, 15, 16, 17, 18$ are not shown. The segment sent at $t=4$ is lost, as is the ACK segment sent at $t=7$.
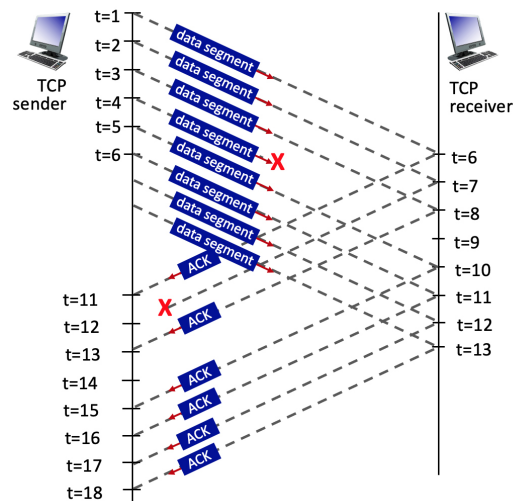
Figure 1: TCP Segment Flow.

33. Referring to Figure 1, what is the sequence number of the segment sent at t=5?

    (A) 0          (B) 100          (C) 200          (**D**) **400**          (E) 500

34. Referring to Figure 1, what is the ACK value carried in the receiver-to-sender ACK sent at t = 6?

    (A) 0          (B) 1          (**C**) **100**          (D) 2          (E) 200

35. Referring to Figure 1, what is the ACK value carried in the receiver-to-sender ACK sent at t = 8?

    (A) 3          (B) 100          (C) 200          (**D**) **300**          (E) 400

36. Referring to Figure 1, what is the ACK value carried in the receiver-to-sender ACK sent at t = 10?

    (A) 3          (B) 100          (C) 200          (**D**) **300**          (E) 400

**Note: the following figure (Figure-2) is used for the next 4 questions.**

Consider the figure below, with 6 sockets shown across the network, and the corresponding Python code at each host. There are four TCP segments in flight. Match the source and destination port numbers for each segment with a value below.
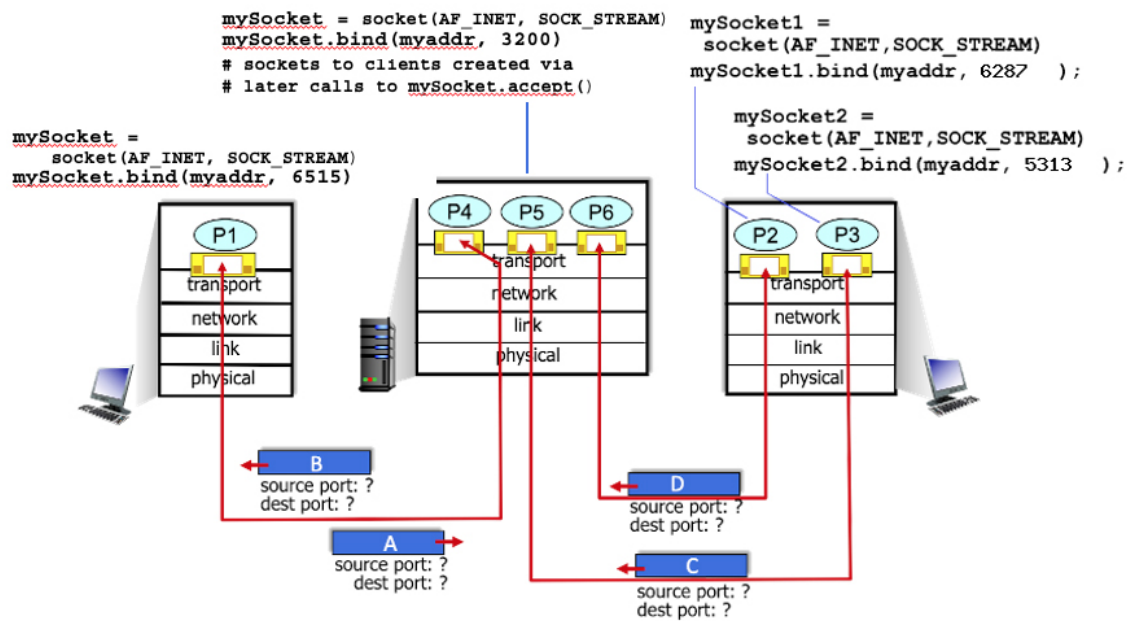
Figure 2: TCP Sockets.

37. Referring to Figure 2, segment A destination port number is:

   (A) 6515       (B) **3200**       (C) 5313       (D) 6287       (E) 443

38. Referring to Figure 2, segment A source port number is:

   (**A**) **6515**       (B) 3200       (C) 5313       (D) 6287       (E) 443

39. Referring to Figure 2, segment C source port number is:

   (A) 6515       (B) 3200       (**C**) **5313**       (D) 6287       (E) 443

40. Referring to Figure 2, segment B source port number is:

   (A) 6515       (B) **3200**       (C) 5313       (D) 6287       (E) 443