

many hosts per subnet does this create?

- (A) 252 (B) 1024
(C) 1022 (D) None of these

Q.19 Which of the following IP addresses are considered ‘network’ addresses with a /28 prefix?

- (A) 165.203.5.192 (B) 165.203.6.255
(C) 165.203.6.240 (D) 165.203.6.255

Q.20 A class C network address has been subnetted with a /28 mask. Which of the following addresses is a broadcast address for one of the resulting subnets?

- (A) 198.57.78.33 (B) 198.57.78.64
(C) 198.57.78.97 (D) 198.57.78.15

Q.21 You are a network administrator and have been assigned the IP address of 201.222.5.0. You need to have 24 subnets with 6 hosts per subnet. The subnet mark is 255.255.255.248. What is the address of 4th subnet?

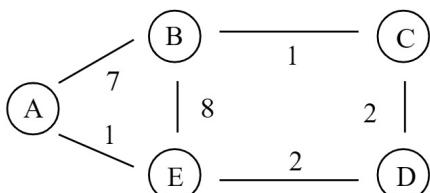
- (A) 201.222.5.10 (B) 201.222.5.1
(C) 201.222.5.16 (D) 201.222.5.24

Q.22 A datagram of 400 bytes (3980 bytes of IP Payload plus 20 bytes of IP Header) arrives at a router and must be

Q.29 A datagram of 4000 bytes (20 bytes of IP Header + 3980 bytes of IP Payload) arrives at a router and must be forwarded the link with MTU of 1500 bytes then at what byte the 2nd fragment is ended?

- (A) 2960 (B) 1480
(C) 2959 (D) 1479

Q.30 Consider the following graph:



The initial state of routing table is

	A	B	C	D	E
A	0	7	∞	∞	1
B	7	0	1	∞	8
C	∞	1	0	2	∞

Q.26 You have a network ID 131.107.0.0 with 8 subnets. You need to allow the largest possible number of hosts/subnet. Which subnet mask should you use?

- (A) 255.255.240.0 (B) 255.255.248.0
(C) 255.255.252.0 (D) 255.255.224.0

Q.27 A router has the following CIDR entries in the routing table

Address/mask	Next hop
135.46.56.0/22	Interface 0
135.46.58.0/22	Interface 1
135.53.40.0/23	Router 1
Default	Router 2

What is the next hop the router routes to, if a packet with the IP address 135.46.63.10 arrives at it?

- (A) Interface 0 (B) Interface 1
(C) Router 1 (D) Router 2

Q.28 IP Address : 124.133.112.66

Mask : 255.255.224.0

Which of the following is not a broadcast address of the subnet?

- (A) 124.133.255.255
(B) 124.133.63.255
(C) Both (A) and (B)
(D) None of these

- (A) 201.15.130.143 (B) 201.15.130.158
(C) 201.15.131.192 (D) 201.12.130.163

Q.34 What will be the valid broadcast address’s fourth byte for subnet 172.16.176.0/20?

- (A) 255 (B) 254
(C) 252 (D) 250

Q.35 Suppose a subnet x has a subnet mask 255.255.192.0 and a system A has IP address 157.106.46.234. Which of the following belongs to same network as A?

- (A) 157.106.63.3
(B) 157.106.132.71
(C) Both (A) and (B)
(D) None of these

Q.36 Find total number of networks in class B IP-Addressing?

- (A) 2^{16} (B) 2^{14}
(C) 2^{24} (D) 2^{12}

D	∞	∞	2	0	2
E	1	8	∞	2	0

If Node B sends vector table to C, then what is updated table result at node C (Distance vector rating protocol)?

- (A) (8, 1, 0, 2, 1)
- (B) (8, 1, 0, 2, 9)
- (C) (8, 1, 0, 4, 2)
- (D) None of these

Q.31 An IPv4 packet has arrived with offset value (60) and value of HLEN field (10_{10}). The value of total length field is (250_{10}). What are the first and last byte numbers respectively?

- (A) 60 and 310
- (B) 480 and 689
- (C) 60 and 289
- (D) 480 and 309

Q.32 An IPv4 packet has the first few hexadecimal digits as shown below.

0X450000 5C 000 30000 9606.....

How many hops can this packet travel before being dropped?

- (A) 105
- (B) 150
- (C) 95
- (D) None of these

Q.33 The IP Address of a host is 201.15.130.137 and its subnet mask is 255.255.255.224. The IP address of the last host of the same subnet is

Q.37 In a network with broadcast ID 200.200.200.159. What is the possible subnet mask in the same network?

- (A) /24
- (B) /25
- (C) /26
- (D) /27

Q.38 Which of the following subnet mask can't be used if two host H(A): x.y.z.155 and H(B): x.y.z.162 belongs to the same network?

- (A) /24
- (B) /25
- (C) /26
- (D) /27

Q.39 Which one of the following field does not change while movement of IP-Packet?

- (A) Total Length
- (B) Identification No.
- (C) TTL
- (D) Checksum

Q.40 You need 500 subnets, each with 100 usable host address per subnet.

What network mask will you assign using a class B network address?

- (A) 255.255.255.252
- (B) 255.255.255.128
- (C) 255.255.255.0
- (D) 255.255.254.0



Q.41 The four byte IP-address consist of
 (A) Network Address only
 (B) Host address only
 (C) Neither Network nor Host address
 (D) Both Network and Host Address

Q.42 What is the slash notation (/n) of subnet mask 255.255.224.0?

- (A) /16
- (B) /18
- (C) /20
- (D) /19

Q.43 In which class the IP-address 239.175.56.0 belongs?

- (A) Class A
- (B) Class B
- (C) Class C
- (D) Class D

Q.44 Which of the following is the last IP Address of class B which can be assigned to a Host?

- (A) x.y.z.254
- (B) x.y.z.255
- (C) x.y.255.254
- (D) x.y.255.255

Q.45 Which of the following IP-Address are NOT used for Private Network?

- (A) 10.0.0.0
- (B) 172.16.0.0

Q.49 Which one of the following field of IP Header may not change on visiting each router?

- (A) Checksum
- (B) TTL
- (C) Offset
- (D) None

Q.50 Which of the following assertion is FALSE about Internet Protocol (IP)?

- (A) IP Packet from source to destination can take different route in the path.
- (B) The checksum filed in IP Header help to detect error in header only not in data.
- (C) The length of IP Packet remains same throughout its journey.
- (D) TTL inside IP Header prevents it to goes into infinite loop.

Q.51 A IP Packet of size 1000 bytes is visiting to a router having maximum transmission unit (MTU) is 200 byes without header. What is the maximum

- (C) 128.0.0.0 (D) 192.168.0.0

Q.46 Which of the following is NOT address resolution technique?

- (A) DHCP (B) DNS
(C) ARP (D) RARP

Q.47 Which of the following statement is FALSE regarding Distance Vector (DV) and Link State (LS) routing protocols?

- (A) In DV, every nodes share it's routing table with it's neighbor periodically.
(B) In LS, every node build it's own minimum spanning tree (MST).
(C) In DV, every node broadcast it's routing table to get distance of other.
(D) In LS, every node broadcast it's query message to get distance of other.

Q.48 Suppose a Host(A) with IP-address 200.200.200.170 belongs to a network with subnet mask 255.255.255.224.

What is the fourth acted of network ID in which Host(A) belongs ?

overhead inside IP Packet if size of network header is 20 bytes (Bytes)?

Q.52 An ISP has the following CIDR based IP-address available with it: 200.200.128.0/20. The ISP wants to give half of this IP- address to Org-A and quarter to Org-B. If first IP-Address will be assigned to a network which consumes more number of IP-address, then what is possible value of 3rd octet of Org-B _____?

Q.53 Suppose Host A wants to send a packet of size 5020 bytes at network layer to Host B. The maximum transmission unit (MTU) of underlying layer of Host A is 1400 bytes without header. If size of header at network layer is 20 bytes, then what is the offset of 3rd fragment that Host B will receive?

Q.54 Suppose an organization wants to create sub-network containing 35,25,10 hosts in each sub-networks. What is the maximum length of subnet mask that organization should use?

- (A) /22 (B) /24
(C) /25 (D) /26

Computer Network

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Q.55 An IP datagram of size 2000 bytes arrives at a router. The router has to forward this packet on a link whose MTU is 300 bytes. Assume size of IP-Header is 20 bytes. The number of fragments that IP datagram will be divided into transmission is?

Q.56 Which of the following statement is NOT TRUE about Distance Vector Routing (DVR) Protocol?

- (A) Every node share it's routing table periodically with it's immediate neighbor if there is a change.
(B) It uses RIP
(C) Count to infinity problems always occur in DVR
(D) Count to infinity problems occurs if there a link failure.

Q.57 Which of the following assertion is NOT TRUE about Internet Control Message Protocol (ICMP)?

- (A) It uses error reporting message to find whether router or host is alive or not.
(B) It uses query message to get specific information from router or host.
(C) The debugging tools like Ping or tracert uses ICMP packet.
(D) ICMP packet is used to get distance of another node.

Q.58 Which one of the following protocols is NOT implemented in Transport Layer?

- (A) Slow Start (B) UDP
(C) ARP (D) Fast Retransmit

4**Transport Layer****Classroom Questions**

Q.1 A TCP server application is programmed to listen on port number P on host S. A TCP client is connected to the TCP server over the network.

Consider that while the TCP connection was active, the server machine S crashed and rebooted. Assume that the client does not use the TCP keepalive timer.

Which of the following behaviors is/are possible?

- (A) The TCP server application on S can listen on P after reboot.
- (B) If the client was waiting to receive a packet, it may wait indefinitely.
- (C) If the client sends a packet after the server reboot, it will receive a RST segment.
- (D) If the client sends a packet after

(C) SYN bit = 1 , SEQ number = Y, ACK bit = 1 , ACK number = X+1, FIN bit = 0

(D) SYN bit = 0 , SEQ number = X+ 1, ACK bit = 0 , ACK number = Y, FIN bit = 1

Q.3

[GATE 2021, IIT Bombay]

Consider a TCP connection between a client and a server with the following specifications; the round trip time is 6 ms, the size of the receiver advertised window is 50 KB, slow-start threshold at the client is 32 KB, and the maximum segment size is 2 KB. The connection is established at time $t = 0$. Assume that there are no timeouts and errors during transmission. Then the size of the congestion window (in KB) at time $t + 60$ ms after all acknowledgements are processed is .

the server reboot, it will receive a FIN segment.

[GATE 2021, IIT Bombay]

- Q.2** Consider the three-way handshake mechanism followed during TCP connection establishment between hosts P and Q. Let X and Y be two random 32-bit starting sequence numbers chosen by P and Q respectively. Suppose P sends a TCP connection request message to Q with a TCP segment having SYN bit = 1, SEQ number = X, and ACK bit = 0. Suppose Q accepts the connection request. Which one of the following choices represents the information present in the TCP segment header that is sent by Q to P?

(A) SYN bit = 1 , SEQ number = X+1 ,
ACK bit =0 , ACK number =Y, FIN bit =0

(B) SYN bit = 1 , SEQ number = Y, ACK bit = 1 , ACK number = X, FIN bit = 0

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Computer Network

[GATE 2020, IIT Delhi]

Consider a long-lived TCP session with an end-to-end bandwidth of 1 Gbps ($= 10^9$ bits-per-second). The session starts with a sequence number of 1234. The minimum time (in seconds, rounded to the closest integer) before this sequence number can be used again is _____.

[GATE 2018, IIT Guwahati]

Match the following :

Field	Length in bits	
P.	UDP Header's Port Number	I. 48
Q.	Ethernet MAC Address	II. 8
R.	IPv6 Next Header	III. 32
S.	TCP Header's Sequence Number	IV. 16

- (A) P-III, Q-IV, R-II, S-I
 (B) P-II, Q-I, R-IV, S-III
 (C) P-IV, Q-I, R-II, S-III
 (D) P-IV, Q-I, R-III, S-II

[GATE 2018, IIT Guwahati]

- Q.6** Consider the following statements regarding the slow start phase of the TCP congestion control algorithm. Note that CWND stands for the TCP congestion window and MSS window denotes the Maximum Segments Size:

 - (i) The CWND increases by 2 MSS on every successful acknowledgment
 - (ii) The CWND approximately doubles on every successful acknowledgement
 - (iii) The CWND increases by 1 MSS every round trip time
 - (iv) The CWND approximately doubles every round trip time

Which one of the following is correct?

- (A) Only (ii) and (iii) are true
 (B) Only (i) and (iii) are true
 (C) Only (iv) is true
 (D) Only (i) and (iv) are true

[GATE 2018, IIT Guwahati]

- ### 9.7 Consider a TCP client and a TCP server

- II. A process can successfully call connect function again for an already connected UDP socket.

- (A) I only (B) II only
 (C) Both I and II (D) Neither I nor II

[GATE 2017, IIT Roorkee]

For a host machine that uses the token bucket algorithm for congestion control, the token bucket has a capacity of 1 megabyte and the maximum output rate is 20 megabytes per second. Tokens arrive at a rate to sustain output at a rate of 10 megabytes per second. The token bucket is currently full and the machine needs to send 12 megabytes of data. The minimum time required to transmit the data is seconds.

- (A) 1.1 sec (B) 1.2 sec
(C) 1.3 sec (D) 1.4 sec

[GATE 2016, IISc Bangalore]

Suppose two hosts use a TCP connection to transfer a large file. Which of the following statements is/are FALSE with respect to the TCP connection?

- i. If the sequence number of a segment is m , then the sequence number of the subsequent

running on two different machines. After completing data transfer, the TCP client calls close to terminate the connection and a FIN segment is sent to the TCP server. Server-side TCP responds by sending an ACK, which is received by the client-side TCP. As per the TCP connection state diagram (RFC 793), in which state does the client-side TCP connection wait for the FIN from the server-side TCP?

- (A) LAST-ACK (B) TIME-WAIT
(C) FIN-WAIT-1 (D) FIN-WAIT-2

[GATE 2017, IIT Roorkee]

Q.8 Consider socket API on a Linux machine that supports connected UDP sockets. A connected UDP socket is a UDP socket on which connect function has already been called. Which of the following statements is/are CORRECT?

- I. A connected UDP socket can be used to communicate with multiple peers simultaneously.

segment is always m+1.

- II. If the estimated round trip time at any given point of time is t sec, the value of the retransmission timeout is always set to greater than or equal to t sec.
III. The size of the advertised window never changes during the course of the TCP connection.
IV. The number of unacknowledged bytes at the sender is always less than or equal to the advertised window.

- (A) III only (B) I and III only
(C) I and IV only (D) II and IV only

[GATE 2015, IIT Kanpur]

Q.11 Identify the correct order in which a server process must invoke the function calls accept, bind, listen, and recv according to UNIX socket API.

- (A) listen, accept, bind, recv
(B) bind, listen, accept, recv
(C) bind, accept, listen, recv

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- (D) accept, listen, bind, recv

[GATE 2015, IIT Kanpur]

Q.12 Consider the following statements.

- I. TCP connections are full duplex
II. TCP has no option for selective acknowledgement
III. TCP connections are message streams
(A) Only I is correct
(B) Only I and III are correct
(C) Only II and III are correct
(D) All of I, II and III are correct

[GATE 2015, IIT Kanpur]

Q.13 Let the size of congestion window of a TCP connection be 32 KB when a timeout occurs. The round trip time of the connection is 100 msec and the maximum segment size used is 2 KB. The time taken (in msec) by the TCP connection to get back to 32 KB congestion window is _____.
(A) 1100 to 1300 (B) 1101 to 1301
(C) 1102 to 1302 (D) 1103 to 1303

[GATE 2014, IIT Kharagpur]

Q.14 Which of the following socket API functions converts an unconnected active TCP socket into a passive socket?
(A) connect (B) bind
(C) listen (D) accept

Q.17 While opening a TCP connection, the initial sequence number is to be derived using a time-of-day (ToD) clock that keeps running even when the host is down. The low order 32 bits of the counter of the ToD clock is to be used for the initial sequence numbers. The clock counter increments once per milliseconds. The maximum packet lifetime is given to be 64s.

Which one of the choices given below is closest to the minimum permissible rate at which sequence numbers used for packets of a connection can increase?

- (A) 0.015/s (B) 0.064/s
(C) 0.135/s (D) 0.327/s

[GATE 2009, IIT Roorkee]

Q.18 What is the maximum size of data that the application layer can pass on to the TCP layer below?

- (A) Any size
(B) 2^{16} bytes - size of TCP header
(C) 2^{16} bytes
(D) 1500 bytes

[GATE 2008, IISc Bangalore]

Q.19 Which of the following system calls results in the sending of SYN packets?
(A) socket (B) bind

- Q.15** The transport layer protocols used for real time multimedia, file transfer, DNS and email, respectively are

 - (A) TCP, UDP, UDP and TCP
 - (B) UDP, TCP, TCP and UDP
 - (C) UDP, TCP, UDP and TCP
 - (D) TCP, UDP, TCP and UDP

[GATE 2013, IIT Bombay]

- Q.16** Consider an instance of TCP's Additive Increase Multiplicative Decrease (AIMD) algorithm where the window size at the start of the slow start phase is 2 MSS and the threshold at the start of the first transmission is 8 MSS. Assume that a timeout occurs during the fifth transmission. Find the congestion window size at the end of the tenth transmission.

(A) 8 MSS (B) 14 MSS
(C) 7 MSS (D) 12 MSS

GATE 2012, IIT Delhi

- Q.22** A client process P needs to make a TCP connection to a server process S. Consider the following situation: the server process S executes a socket(), a bind() and a listen() system call in that order, following which it is preempted. Subsequently, the client process P executes a socket() system call followed by connect() system call to connect to the server process S. The server process has not executed any accept() system call. Which one of the following events could take place?

 - (A) connect() system call returns successfully
 - (B) connect() system call blocks
 - (C) connect() system call returns an error
 - (D) connect() system call results in a core dump

[GATE 2008, IISc Bangalore]

- Q.23** Which of the following statements are TRUE?

S1 : TCP handles both congestion and flow control

S2 : UDP handles congestion but not flow control

S3 : Fast retransmit deals with congestion but not flow control

S4 : Slow start mechanism deals with both congestion and flow control

(A) S1, S2 and S3 only

[GATE 2008, IISc Bangalore]

- Q.20** In the slow start phase of the TCP congestion control algorithm, the size of the congestion window :

 - (A) does not increase
 - (B) increase linearly
 - (C) increases quadratically
 - (D) increases exponentially

[GATE 2008, IISc Bangalore]

- Q.21** A computer on a 10 Mbps network is regulated by a token bucket. The token bucket is filled at a rate of 2 Mbps. It is initially filled to capacity with 16 Megabits. What is the maximum duration for which the computer can transmit at the full 10 Mbps?

(A) 1.6 seconds (B) 2 seconds
(C) 5 seconds (D) 8 seconds

[GATE 2008, IISc Bangalore]



- S3** : The server moves LISTEN→SYN_RCVD→SYN_SENT→ESTABLISHED in the state machine on no packet loss

- S4** : The server moves LISTEN→SYN_RCVD→ESTABLISHED in the state machine on no packet loss

- (A) S2 and S3 only (B) S1 and S4 only
(C) S1 and S3 only (D) S2 and S4 only

[GATE 2008, IISc Bangalore]

- Q.25** Consider the following statements about the timeout value used in TCP.

 - (i) The timeout value is set to the RTT (Round Trip Time) measured during TCP connection establishment for the entire duration of the connection.
 - (ii) Appropriate RTT estimation algorithm is used to set the timeout value of a TCP connection.
 - (iii) Timeout value is set to twice the propagation delay from the sender to the receiver.

Which of the following choices hold?

- (A) (i) is false, but (ii) and (iii) are true
 - (B) (i) and (iii) are false, but (ii) is true
 - (C) (i) and (ii) are false, but (iii) is true
 - (D) (i), (ii) and (iii) are false

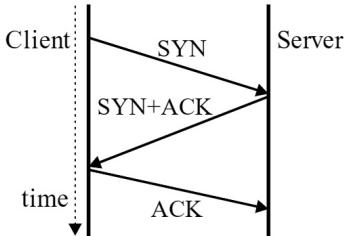
[GATE 2007 IIT Kharagpur]

- Q.26** Consider a TCP connection in a state where there are no outstanding ACKs. The sender sends two segments back-

- (A) S1 and S3 only
 (C) S3 and S4 only
 (D) S1, S3 and S4 only

[GATE 2008, IISc Bangalore]

- Q.24** The three way handshake for TCP connection establishment is shown below.



Which of the following statements are TRUE?

- S1 :** Loss of SYN+ACK from the server will not establish a connection
S2 : Loss of ACK from the client cannot establish the connection

to back. The sequence numbers of the first and second segments are 230 and 290 respectively. The first segment was lost, but the second segment was received correctly by the receiver. Let X be the amount of data carried in the first segment (in bytes), and Y be the ACK number sent by the receiver.

- The values of X and Y (in that order) are
 (A) 60 and 290 (B) 230 and 291
 (C) 60 and 231 (D) 60 and 230

[GATE 2007, IIT Kanpur]

- Q.27** A program on machine X attempts to open a UDP connection to port 5376 on a machine Y, and a TCP connection to port 8632 on machine Z. However, there are no applications listening at the corresponding ports on Y and Z. An ICMP Port Unreachable error will be generated by

- (A) Y but not Z (B) Z but not Y
 (C) Neither Y nor Z (D) Both Y and Z

[GATE 2006, IIT Kharagpur]

- Q.28** Packets of the same session may be routed through different paths in:

- (A) TCP, but not UDP
 (B) TCP and UDP
 (C) UDP, but not TCP
 (D) Neither TCP nor UDP

[GATE 2005, IIT Bombay]

- Q.29** On a TCP connection, current congestion window size is Congestion Window = 4 KB. The window size advertised by the receiver is Advertise Window = 6 KB. The last byte sent by the sender is LastByteSent = 10240 and the last byte acknowledged by the receiver is LastByteAcked = 8192. The current window size at the sender is:

- (A) 2048 bytes (B) 4096 bytes
 (C) 6144 bytes (D) 8192 bytes

[GATE 2005, IIT Bombay]

- Q.30** Which one of the following statements is FALSE?

- (A) TCP guarantees a minimum communication rate
 (B) TCP ensures in-order delivery
 (C) TCP reacts to congestion by reducing sender window size
 (D) TCP employs retransmission to compensate for packet loss

- Q.32** Suppose that the maximum transmit window size for a TCP connection is 12000 bytes. Each packet consists of 2000 bytes. At some point in time, the connection is in slow-start phase with a current transmit window of 4000 bytes. Subsequently, the transmitter receives two acknowledgments. Assume that no packets are lost and there are no time-outs. What is the maximum possible value of the current transmit window?

- (A) 4000 bytes (B) 8000 bytes
 (C) 10000 bytes (D) 12000 bytes

[GATE 2004, IIT Delhi]

- Q.33** Which one of the following statements is FALSE?

- (A) TCP guarantees a minimum communication rate
 (B) TCP ensures in-order delivery
 (C) TCP reacts to congestion by reducing sender window size
 (D) TCP employs retransmission to compensate for packet loss

[GATE 2004, IIT Delhi]

- Q.34** Assume that the bandwidth for a TCP connection is 1048560 bits/sec. Let α be the value of RTT in milliseconds (rounded off to the nearest integer) after which the TCP window scale option is needed. Let β be the maximum possible window size with window scale option. Then the values

- Q.31** In TCP, a unique sequence number is assigned to each
 (A) byte (B) word
 (C) segment (D) message

[GATE 2004, IIT Delhi]

of α and β are

- (A) 63 milliseconds, 65535×2^{14}
 (B) 63 milliseconds, 65535×2^{16}
 (C) 500 milliseconds, 65535×2^{14}
 (D) 500 milliseconds, 65535×2^{16}

[GATE 2015, IIT Kanpur]

Practice Questions

- Q.1** Suppose you are browsing the world wide web using a web browser and trying to access the web servers. What is the underlying protocol and port number that are being used?
 (A) UDP, 80 (B) TCP, 80
 (C) TCP, 25 (D) UDP, 25

- Q.2** An ACK number of 1000 in TCP always means that

- (A) 999 bytes have been successfully received
 (B) 1000 bytes have been successfully received
 (C) 1001 bytes have been successfully received
 (D) None of the above

- Q.3** Assuming that for a given network layer implementation, connection



establishment overhead is 100 bytes and disconnection overhead is 28 bytes. What would be the minimum size of the packet the transport layer needs to keep up, if it wishes to implement a datagram service above the network needs to keep its overhead to a minimum of 12.5%. (Ignore transport layer overhead)

- (A) 512 bytes (B) 768 bytes
 (C) 1152 bytes (D) 1024 bytes

- Q.4** A simple and reliable data transfer can be accomplished by using the 'handshake protocol'. It accomplishes reliable data transfer because for every data item sent by the transmitter _____.

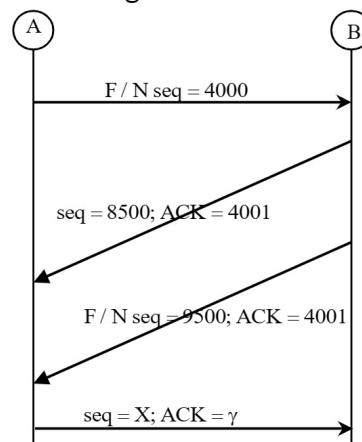
- Q.5** Consider "Additive Increase Multiplicative Decrease" approach of TCP congestion control. One MSS (Maximum segment size) is 512 bytes. If the TCP sender doesn't perceive the path as not congested, then what will be congestion window after 2 RTTs provided the congestion window is assigned 1MSS initially?

- (A) 512 bytes (B) 2048 bytes
 (C) 2560 bytes (D) 1536 bytes

- Q.6** A TCP machine is sending window size of 65,535 bytes over 1Gbps channel that has a 20ms one-way latency. What is the maximum throughput?

- (A) 37 bits (B) 34 bits
 (C) 30 bits (D) 32 bits

- Q.10** TCP Connection using 3-way handshaking is shown below



Consider the following statement about this termination:

S₁: X's Value is 4000

S₂: Y's Value is 9500

Which of the above statements is/are TRUE?

- (A) S₁ Only
 (B) S₂ Only
 (C) Both
 (D) Neither S₁ and S₂

- Q.11** A TCP host has receiver window size of 1 KB and a congestion window size of 2 KB. What is the window size of that host?

- (A) 2 KB (B) 1 KB
 (C) 3 KB (D) None of these

- Q.12** Which of the following statements

Q.7 A computer on a 6Mbps network regulated by a token bucket. The token bucket is filled at a rate of 2 Mbps. It is initially filled to capacity with 4 megabits. How long can the computer transfer at the full 4Mbps? (in seconds)

Q.8 Suppose that the TCP congestion window is set to 18KB and a timeout occurs. How big will the window be in the 6th transmission if the next 4 transmission bursts are all successful? (Assume 1MSS=1KB)

Q.9 In a 4Gbps line, it takes 2 seconds to wrap around the sequence number. How many bits were used for sequence Number?

S₁: TCP is a message-oriented protocol
S₂: UDP is an unreliable connectionless protocol
(A) S₁ only (B) S₂ only
(C) Both (D) None of these

Q.15 Which of the following is a feature of UDP?
(A) Flow control (B) Error control
(C) Both A & B (D) None

Q.16 For a system using TCP, the sender window size is determined by _____ window size.
(A) Receiver (B) Congestion
(C) Both (D) None of these

Q.17 In connection establishment phase of TCP, for confirmation, the TCP header fields SYN(s), ACK(A) contain values
(A) S=0, A=0 (B) S=0, A=1
(C) S=1, A=0 (D) S=1, A=1

Q.18 The number of packets required in TCP connection establishment phase is
(A) 2 (B) 3
(C) 4 (D) 1

Q.19 In a TCP connection, current congestion window size is 2 KB. The window size advertised by the receiver is 3 KB. The last byte sent by the sender is 5120 and the last byte acknowledged by the receiver is 4096. The current window size at the sender is _____ (in KB).

Q.20 Which of the following is CORRECT?
S₁: Transport layer is responsible for process to process delivery
S₂: TCP is a connectionless practice.

is/are FALSE?

S₁: TCP Provides end to end connection.

S₂: TCP ensures that data is delivered reliably in sequence and without error.

- (A) S₁ Only
- (B) S₂ Only
- (C) Both S₁ & S₂
- (D) Neither S₁ and S₂

Q.13 In TCP, sequence number is used for
(A) Rearranging the data of receiver end before passing to the application.
(B) Detecting duplicate data
(C) Both
(D) None of these.

Q.14 Which of the following statement/s is/are TRUE?

S₂: In UDP, inclusion of checksum is optional

- (A) S₁ only (B) S₂ only
(C) Both (D) Neither S₁ nor S₂

Q.23 Which of the following statements is FALSE about TCP?

- (A) It uses sequence number field for inorder delivery of data segments
- (B) It is connection oriented protocols so all packets follow same path.
- (C) It is responsible for end to end delivery of data segments
- (D) It is used in an application in which reliability is must.

Q.24 Which of the following is NOT part of UDP header?

- (A) Checksum
- (B) Source port
- (C) Sequence number
- (D) Total length

Q.25 Which of the following statement is NOT True?

- (A) TCP assigns sequence number to each byte
- (B) TCP assign sequence number only to the first byte of segment
- (C) TCP uses 32- bits for sequence number field.
- (D) Byte numbering is used for flow control

Q.26 Which of the following field is NOT included in TCP Header?

...

S₃: UDP ensures in-order delivery

- (A) S₁ only
- (B) S₂ only
- (C) S₂ and S₃
- (D) None of these

Q.21 TCP sender received an ACK with sequence number as 1024 from receiver what would be the segment number of the next segment that will be sent by the sender to receiver?

- (A) 1025
- (B) 1024
- (C) 1023
- (D) None of these

Q.22 Which of the following statement/s is/are TRUE?

S₁: In UDP, checksum is used to detect errors over both header & data

(A) Sequence number

(B) Acknowledgement number

(C) Checksum

(D) Protocol

Q.27 Consider the following assertions :

S1: TCP uses checksum field for error control

S2: TCP uses sequence number field for flow control

S3: TCP window size is varying depending upon congestion of networks.

Which of the following is/are TRUE?

- (A) S₁, S₂
- (B) S₂, S₃
- (C) S₁, S₃
- (D) All

Q.28 Suppose size of receiver window is 20 KB and size of congestion window is 10 KB. What should be the size of sender window to maintain flow control?

- (A) 30 KB
- (B) 20 KB
- (C) 10 KB
- (D) Could be 10 KB or 20 KB

Q.29 Suppose size of current window of sender is 2MSS (Maximum segment size) and sender is using Slow Start congestion control protocol. If threshold value of networks is 8MSS then find the sender window size after 5 RTT?

Q.30 Suppose size of each segment is 2000 bytes and current sender window size is 6000 bytes. Sender received three ACK subsequently then what is the sender window size if Slow Start protocol is used?

- (A) 6000 bytes
- (B) 8000 bytes
- (C) 10000 bytes
- (D) 12000 bytes

Q.31 Initially sender detected that size of receiver window is 6 MSS and congestion window size is 4 MSS. After one RTT, what will be the sender window size if Slow Start protocol is used (in MSS)?

Q.32 Which of the following statements is/are TRUE about UDP?

- S₁ : It uses three way handshaking process to established connection.
- S₂ : Header size of UDP packet is fixed and of 8 bytes.

Q.34 Suppose TCP connection is transferring file size of 5000 bytes. The first byte number is 2001. What is the sequence number of third segment if each segment carry 1000 byte?

Q.35 Consider the following assertion :

S₁ : Slow start phase follows exponential growth.

S₂ : Congestion avoidance phase follows additive increase.

S₃ : In fast retransmit if there is loss of segment at any point of time then it moves to slow start phase again.

- (A) S₁, S₂
- (B) S₂, S₃
- (C) S₁, S₃
- (D) All

Q.46 Suppose sender has sent bytes upto 202. Assume Congestion window size is 20 bytes. The receiver has sent an ACK No of 200 with receiver window size of 9 bytes. What is the sequence number of last byte inside sender window?

Q.37 Suppose initial window size of sender is 1 MSS and it uses Slow Start phase with threshold value of 16 MSS. Assume that the lost is detected at 8th RTT by timeout. What is the sender window size after 12th RTT _____ (MSS)?

Q.38 Consider the following assertion :

S₁ : In congestion control protocol the loss can be detected by timeout or by three duplicate acknowledgement.

S₂ : If loss is detected by timeout then new slow start phase is started with sender window size 1MSS.

S3 : It is used for application layer where reliability is not required.

- (A) S1, S2
- (B) S3
- (C) S2, S3
- (D) All

Q.33 In which of the following, the UDP protocol is NOT suitable to use?

- (A) FTP
- (B) TFTP
- (C) SNMP
- (D) RIP

S3 : If loss is detected by three duplicate ACK then new congestion avoidance phase with sender window size half of current window size.

- (A) S1, S2
- (B) S1, S3
- (C) S2, S3
- (D) All



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Application Layer



Classroom Questions

Q.1 Which of the following protocol pairs can be used to send and retrieve e-mails (in that order)?

- (A) SMTP MIME
- (B) SMTP, POP3
- (C) IMAP POP3
- (D) IMAP, SMTP

[GATE 2019, IIT Madras]

Q.2 Assume that you have made a request for a web page through your web browser to a web server. Initially the browser cache is empty. Further, the browser is configured to send HTTP requests in non-persistent mode. The web page contains text and five very small images. The minimum number of TCP connections required to display the web page completely in your browser is _____.

[GATE 2020, IIT Delhi]

Q.3 Which of the following is/are example(s) of stateful application layer protocol?

- (i) HTTP
 - (ii) FTP
 - (iii) TCP
 - (iv) POP3
- (A) (i) and (ii) only
 - (B) (ii) and (iii) only
 - (C) (ii) and (iv) only
 - (D) (iv) only

[GATE 2016, IISc Bangalore]

Q.4 Identify the correct sequence in which the following packets are transmitted on the network by a host when a

Q.5 Which one of the following statements is NOT correct about HTTP cookies?

- (A) A cookie is a piece of code that has the potential to compromise the security of an Internet user
- (B) A cookie gains entry to the user's work area through an HTTP header
- (C) A cookie has an expiry date and time
- (D) Cookies can be used to track the browsing pattern of a user at a particular site

[GATE 2015, IIT Kanpur]

Q.6 Identify the correct order in which the following actions take place in an interaction between a web browser and a web server.

1. The web browser requests a webpage using HTTP.
 2. The web browser establishes a TCP connection with the web server.
 3. The web server sends the requested webpage using HTTP.
 4. The web browser resolves the domain name using DNS.
- (A) 4,2,1,3
 - (B) 1,2,3,4
 - (C) 4,1,2,3
 - (D) 2,4,1,3

[GATE 2014, IIT Kharagpur]

Q.7 The protocol data unit (PDU) for the application layer in the Internet stack

browser requests a webpage from a remote server, assuming that the host has just been restarted.

- (A) HTTP GET request, DNS query, TCP SYN
- (B) DNS query, HTTP GET request, TCP SYN
- (C) DNS query, TCP SYN, HTTP GET request
- (D) TCP SYN, DNS query, HTTP GET request

[GATE 2016, IISc Bangalore]

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is:

- (A) Segment
- (B) Datagram
- (C) Message
- (D) Frame

[GATE 2012, IIT Delhi]

Q.8 Which of the following transport layer protocols is used to support electronic mail?

- (A) SMTP
- (B) IP
- (C) TCP
- (D) UDP

[GATE 2012, IIT Delhi]

Q.9 Which one of the following is not a client server application?

- (A) Internet chat
- (B) Web browsing
- (C) E-mail
- (D) Ping

[GATE 2010, IIT Guwahati]

Q.10 Which one of the following uses UDP as the transport protocol?

- (A) HTTP
- (B) Telnet
- (C) DNS
- (D) SMTP

[GATE 2007, IIT Kanpur]

Q.11 Match the following :

P.	SMTP	1.	Application layer
Q.	BGP	2.	Transport layer
R.	TCP	3.	Data link layer
S.	PPP	4.	Network layer
		5.	Physical layer

- (A) P-2, Q-1, R-3, S-5
- (B) P-1, Q-4, R-2, S-3
- (C) P-1, Q-4, R-2, S-5
- (D) P-2, Q-4, R-1, S-3

[GATE 2007, IIT Kanpur]

Q.12 Consider the following clauses :

- i. Not inherently suitable for client authentication.
- ii. Not a state sensitive protocol.
- iii. Must be operated with more than one server.
- iv. Suitable for structured message organization.
- v. May need two ports on the server side for proper operation.

The option that has the maximum number of correct matches is

- (A) IMAP-i; FTP-ii; HTTP-iii; DNS-iv; POP3-v
- (B) FTP-i; POP3-ii; SMTP-iii; HTTP-iv; IMAP-v
- (C) POP3-i; SMTP-ii; DNS-iii; IMAP-iv; HTTP-v
- (D) SMTP-i; HTTP-ii; IMAP-iii; DNS-iv; FTP-v

Q.14 Consider the three commands : PROMPT, HEAD and RCPT. Which of the following options indicate a correct association of these commands with protocols where these are used?

- (A) HTTP, SMTP, FTP
- (B) FTP, HTTP, SMTP
- (C) HTTP, FTP, SMTP
- (D) SMTP, HTTP, FTP

[GATE 2005, IIT Bombay]

Q.15 Assume that “host1.mydomain.dom” has an IP address of 145.128.16.8. Which of the following options would be most appropriate as a subsequence of steps in performing the reverse lookup of 145.128.16.8? In the following options “NS” is an abbreviation of “nameserver”.

- (A) Query a NS for the root domain and then NS for the “dom” domains
- (B) Directly query a NS for “dom” and then a NS for “mydomain.dom” domains
- (C) Query a NS for in-addr.arpa and then a NS for 128.145.in-addr.arpa domains
- (D) Directly query a NS for 145.in-addr.arpa and then a NS for 128.145.in-addr.arpa domains

[GATE 2005, IIT Bombay]

Q.16 HELO and PORT, respectively, are commands from the protocols:

- (A) FTP and HTTP
- (B) TELNET and POP3
- (C) HTTP and TELNET
- (D) SMTP and FTP

[GATE 2006, IIT Kharagpur]

Q.17 Consider the different activities related to email.

m1 : Send an email from mail client to mail.com

- Q.13** Which one of the following statements is FALSE?
- HTTP runs over TCP
 - HTTP describes the structure of web pages
 - HTTP allows information to be stored in a URL
 - HTTP can be used to test the validity of a hypertext link

[GATE 2004, IIT Delhi]



- Q.18** In one of the pairs of protocols given below, both the protocols can use multiple TCP connections between the same client and the server. Which one is that?

- HTTP, FTP
- HTTP, TELNET
- FTP, SMTP
- HTTP, SMTP

[GATE 2015, IIT Kanpur]

Practice Questions

- Q.1** A packet filtering firewall can
- Deny certain users from accessing a service
 - Block worms and viruses from entering the network
 - Disallow some files from being accessed through FTP
 - Block some hosts from accessing the network
- Q.2** Which of the following protocol is used for transferring electronic mail messages from one machine to another?
- TELNET
 - FTP
 - SNMP
 - SMTP
- Q.3** Generally TCP is reliable and UDP is not reliable. DNS which has to be reliable uses UDP because
- UDP is slower
 - DNS servers has to keep connections
 - DNS requests are generally very small and fit well within UDP segments
 - None of these

- Q.4** Consider the set of activities related to e-mail
- A :** Send an e-mail from a mail client to mail server.
- B :** Download e-mail headers from mailbox and retrieve mails from server to cache.
- C :** Checking e-mail through a web browser.

- File server
- DNS server
- DHCP server
- Default gateway

- Q.6** Distance vector routing algorithm is a dynamic routing algorithm. The routing tables in distance vector routing algorithm are updated _____.

- automatically
- by server
- by exchanging information with neighbour nodes
- with back up database

- Q.7** Which of the following statement(s) is/are false?

- S1: DNS maps the IP address to URL address

- S2: FTP uses UDP as a transport protocol

- S1 only
- S2 only
- Both
- None of these

- Q.8** Which of the following is TRUE about DNS?

- DNS uses only UDP protocol.
- DNS uses only TCP protocol.
- DNS can use either TCP or UDP depending upon response of message size.
- None

- Q.9** Which of the following are FALSE?

- DNS can use either TCP or UDP protocol.
- DNS uses well known port 53.
- DNS is used to find IP-address with

- m2 :** Download an email from mailbox server to a mail client

- m3 :** Checking email in a web browser
Which is the application level protocol used in each activity?

- m1: HTTP m2 : SMTP m3 : POP
- m1: SMTP m2 : FTP m3 : HTTP
- m1: SMTP m2 : POP m3 : HTTP
- m1: POP m2 : SMTP m3 : IMAP

[GATE 2011, IIT Madras]

The application level protocol used for each activity in the same sequence is

- (A) SMTP, HTTPS, IMAP
- (B) SMTP, POP, IMAP
- (C) SMTP, IMAP, HTTPS
- (D) SMTP, IMAP, POP

Q.5 A packet whose destination is outside the local TCP/IP network segment is sent to _____.

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Computer Network

(C) DNS matches name space from root to leaf or from leaf to root of tree.

(D) Each node in tree has domain name.

Q.11 Which of the following program is not used in internet to provide electronic mail services?

- (A) SMTP
- (B) POP3
- (C) IMAP4
- (D) ICMP

Q.12 Which of the following statements is incorrect?

- (A) In electronics mail, MIME allows the transfer of multimedia messages.
- (B) In electronic mail, MTA transfers the mail across internet.
- (C) POP3 and IMAP4 protocols are used for polling messages from mail server.
- (D) None

MAC address.

(D) DNS uses TCP if response message size is less than 512 bytes.

Q.10 Which of the following statement is FALSE about DNS operation?

- (A) DNS is client-server architecture.
- (B) DNS organizes the name space in decentralize manner.



Q.13 Consider the following statements :

S1 : WWW is repository of information.

S2 : Hypertexts are documents.

S3 : Browser interpret and display a web documents.

S4 : Common Gateway Interface (CGI) is a protocol.

- (A) S1, S2, S4
- (B) S1, S2, S3
- (C) S1, S3, S4
- (D) All

Q.14 Which of the following statements is incorrect about HTTP?

- (A) HTTP uses TCP connection transfer files.
- (B) HTTP is a protocol used to access world wide web (WWW)
- (C) TCP uses any port number for HTTP connection.
- (D) HTTP message is similar to SMTP message.

□□□

Operating System

1

Process Management - I



Classroom Questions

[GATE 2002, IISc Bangalore]

- Q.2** What is the objective of multiprogramming?

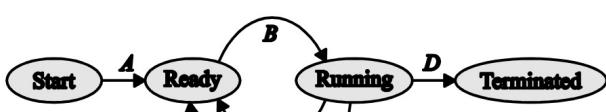
 - (A) Have a process running at all time
 - (B) Have multiple programs waiting in a queue ready to run
 - (C) To increase CPU utilization
 - (D) None of the mentioned

Q.3 In operating system, each process has its own

- its own _____

 - (A) Address space and global variables
 - (B) List of open files
 - (C) Process Control Block
 - (D) all of the mentioned

Q.4 In the following process state transition diagram for a uniprocessor system, assume that there are always some processes in the ready state:



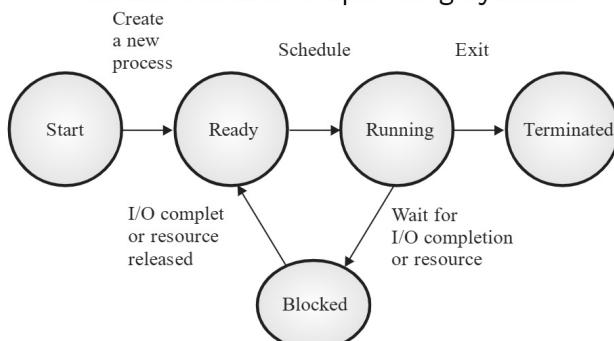
Now consider the following statements:

- I. If a process makes a transition D, it would result in another process making transition A immediately.
 - II. A process P₂ in blocked state can make transition E while another process P₁ is in running state.
 - III. The OS uses preemptive scheduling.
 - IV. The OS uses non-preemptive scheduling.

Which of the above statements are true?

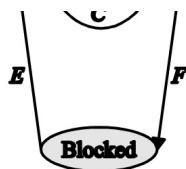
[GATE 2009 : IIT Roorkee]

- Q.5** The process state transition diagram of an operating system is as given below. Which of the following must be FALSE about the above operating system?



- (A) It is a multiprogrammed operating system
 - (B) It uses preemptive scheduling
 - (C) It uses non-preemptive scheduling
 - (D) It is a multi-user operating system

[GATE 2006 : IIIT Kharagpur]



- Q.7** System calls are usually invoked by using :
(A) A software interrupt

[GATE 1999 : IIT Bombay]

- Q.8** A processor needs software interrupt to
(A) Test the interrupt system of the processor.
(B) Implement co-routines.
(C) Obtain system services which need execution of privileged instructions.
(D) Return from subroutine.

[GATE 2001 : IIT Kanpur]

- Q.9** A Computer handles several interrupt sources of which the following are relevant for this question:

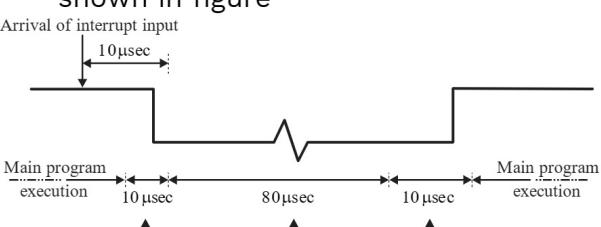
 - Interrupt from CPU temperature sensor (raises interrupt if CPU temperature is too high)
 - Interrupt from Mouse (raises interrupt if the mouse is moved or a button is pressed)
 - Interrupt from keyboard (raises interrupt when a key is pressed or release)
 - Interrupt from Hard Disk (raise interrupt when a disk read is completed)

Which one of these will be handled at the HIGHEST priority?

- (A) Interrupt from Hard Disk
(B) Interrupt from Mouse
(B) Interrupt from Keyboard
(D) Interrupt from CPU temperature sensor.

[GATE 2011 : IIT Madras]

- Q.10** The details of an interrupt cycle are shown in figure



the total time that the CPU devotes for the main program execution.

[GATE 1993 : IIT Bombay]

- Q.11** Let the time taken to switch between user and kernel modes of execution be t_1 while the time taken to switch between two processes be t_2 . Which of the following is TRUE?

 - (A) $t_1 > t_2$
 - (B) $t_1 = t_2$
 - (C) $t_1 < t_2$
 - (D) Nothing can be said about the relation between t_1 and t_2 .

[GATE 2011 : IIT Madras]

Q.13 The following C program is executed on a Unix/Linux system:

```
#include <unistd.h>
int main ()
{
    int i;
    for (i=0; i<10; i++)
        if (i% 2 == 0) fork();
    return 0;
}
```

The total number of child processes created is .

[GATE 2019 : IIT Madras]

- Q.14** Consider the following code fragment:

```
if (fork() == 0)
{
    a = a + 5;
    printf("%d,%d\n", a, &A);
```



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Operating System

Let u , v be the values printed by the parent process, and x , y be the values printed by the child process. Which one of the following is TRUE?

- (A) $u = x + 10$ and $v = y$
- (B) $u = x + 10$ and $v \neq y$
- (C) $u + 10 = x$ and $v = y$
- (D) $u + 10 = x$ and $v \neq y$

[GATE 2005 : IIT Bombay]

Q.15 Consider the following statements about user level threads and kernel threads. Which one of the following statements is FALSE?

- (A) Context switch time is longer for kernel level threads than for user level threads.
- (B) User level threads do not need any hardware support.
- (C) Related kernel level threads can be scheduled on different processors in a multi-processor system.
- (D) Blocking one kernel level thread blocks all related threads.

[GATE 2007 : IIT Kanpur]

Q.16 A thread is usually defined as a “light weight process” because an operating system (OS) maintains smaller data structures for a thread than for a process. In relation to this, which of the following is TRUE?

- (A) On per-thread basis, the OS maintains only CPU register state.
- (B) The OS does not maintain a separate stack for each thread.
- (C) On per-thread basis, the OS does not maintain virtual memory state.
- (D) On per-thread basis, the OS maintains only scheduling and accounting information.

[GATE 2011 : IIT Madras]

Q.17 Which one of the following is FALSE?

- (A) User level threads are not scheduled by the kernel.
- (B) When a user level thread is blocked,

```

    }
else { a = a -5; printf("%d, %d\n", a,
&A); }

```



(C) Context switching between user level threads is faster than context switching between kernel level threads.

(D) Kernel level threads cannot share the code segment.

[GATE 2014 : IIT Kharagpur]

Q.18 Threads of a process share

- (A) Global variables but not heap
- (B) Head but not global variables
- (C) Neither global variables nor heap
- (D) Both heap and global variables

[GATE 2017 : IIT Roorkee]

Q.19 Which of the following is/are shared by all the threads in a process?

- I. Program counter
 - II. Stack
 - III. Address space
 - IV. Registers
- | | |
|-------------------|---------------------|
| (A) I and II only | (B) III only |
| (C) IV only | (D) III and IV only |

[GATE 2017 : IIT Roorkee]

Q.20 Consider the following table of arrival time and burst time for three processes P0, P1 and P2.

Processes	Arrival time	Burst time
P0	0 ms	9 ms
P1	1 ms	4 ms
P2	2 ms	9 ms

The pre-emptive shortest job first scheduling algorithm is used.

Scheduling is carried out only at arrival or completion of processes.

What is the average waiting time for the three processes?

- | | |
|-------------|-------------|
| (A) 5.0 ms | (B) 4.33 ms |
| (C) 6.33 ms | (D) 7.33 ms |

[GATE 2011 : IIT Madras]

Q.21 An operating system uses shortest remaining time first scheduling algorithm for pre-emptive following of processes. Consider the following set

Process	Arrival time	Burst time
P1	0	12
P2	2	4
P3	3	6
P4	8	5

The average waiting time (in milliseconds) of the processes is

[GATE 2014 : IIT Kharagpur]

- Q.22** Consider the following set of processes that need to be scheduled on a single CPU. All the times are given in milliseconds.

Process Name	Arrival time	Execution Time
A	0	6
B	3	2
C	5	4
D	7	6
E	10	3

Using the shortest remaining time first scheduling algorithm, the average process turnaround time (in msec) is .

[GATE 2014 : IIT Kharagpur]

- Q.23** An operating system uses Shortest Remaining Time First (SRT) process scheduling algorithm. Consider the arrival times and execution times for the following processes:

Process	Execution time	Arrival Time
P1	20	0
P2	25	15
P3	10	30
P4	15	45

What is the total waiting time for process P2?

[GATE 2007 : IIT Kanpur]

- Q.24** Consider three CPU-intensive processes, which require 10, 20 and 30

ot processes with their arrival time and CPU burst time (in millisecond) :

time units and arrive at times 0, 2 and 6 respectively. How many context switches are needed if the operating system implements a shortest remaining time first scheduling algorithm? (Do not count the context switches at time zero and at the end)

[GATE 2006 : IIT Kharagpur]

- Q.25** Consider the following four processes with arrival times (in milliseconds) and their length of CPU bursts (in milliseconds) as shown below :

Process	P1	P2	P3	P4
Arrival time	0	1	3	4
CPU burst time	3	1	3	2

These processes are run on a single processor using preemptive Shortest Remaining Time First scheduling algorithm. If the average waiting time of the processes is 1 milliseconds, then the value of Z is .

[GATE 2019 : IIT Madras]

- Q.26** Consider three processes, all arriving at time zero, with total execution time of 10, 20 and 30 units, respectively. Each process spends the first 20% of execution time doing I/O, the next 70% of time doing computation and the last 10% of time doing I/O again. The operating system uses a shortest remaining compute time first scheduling algorithm and schedules a new process either when the running processes gets blocked on I/O or when the running process finishes its compute burst. Assume that all I/O operations can be overlapped as much as possible. For what percentage of time does the CPU remain idle?

- [GATE 2006 : IIT Kharagpur]**
- Q.27** Consider the set of processes with arrival time (in milliseconds). CPU burst time (in milliseconds). And priority (0 is the highest priority) shown below.

Process	Arrival Time (ms)	Priority	Initial CPU Burst Time (ms)	Remaining CPU Burst Time (ms)	I/O Burst Time (ms)	Remaining CPU Burst Time (ms)
P ₁	0	0	10	10	0	10
P ₂	10	1	10	10	0	10
P ₃	20	2	10	10	0	10
P ₄	30	3	10	10	0	10
P ₅	40	4	10	10	0	10

None of the processes have I/O burst time.



Process	Arrival Time	Burst Time	Priority
P_1	0	11	2
P_2	5	28	0
P_3	12	2	3
P_4	2	10	1
P_5	9	16	4

The average waiting time (in millisecond) of all the processes using preemptive priority scheduling algorithm is _____.

[GATE 2017 : IIT Roorkee]

- Q.28** The arrival time, priority, and duration of the CPU and I/O bursts for each of three processes P_1 , P_2 and P_3 are given in the table below. Each process has a CPU burst followed by an I/O burst followed by another CPU burst. Assume that each process has its own I/O resource.

Process	Arrival Time	Priority	Burst Duration CPU, I/O, CPU
P_1	0	2	1, 5, 3
P_2	2	3 (lowest)	3, 3, 1
P_3	3	1 (highest)	2, 3, 1

The multi-programmed operating system uses preemptive priority scheduling. What are the finish times of the processes P_1 , P_2 and P_3 ?

- (A) 11, 15, 9 (B) 10, 15, 9
 (C) 11, 16, 10 (D) 12, 17, 11

[GATE 2006 : IIT Kharagpur]

- Q.29** Consider a uniprocessor system executing three task T_1 , T_2 and T_3 each of which is composed of an infinite sequence of jobs (or instances) which arrive periodically at intervals of 3, 7 and 20 milliseconds, respectively. The priority of each task is the inverse of its period, and the available tasks are scheduled in order of priority, with the highest priority task scheduled first.

Each instance of T_1 , T_2 & T_3 requires an execution time of 1, 2 and 4 milliseconds, respectively. Given that all task initially arrive at the beginning of the 1st millisecond and task pre-emption are allowed. The first instance of T_3 completes its execution at the end of _____ millisecond.

[GATE 2015 : IIT Kanpur]

- Q.30** Four jobs to be executed on a single processor system arrive at time 0^+ in the order A, B, C, D. Their burst CPU time requirements are 4, 1, 8, 1 time units respectively. The completion time of A under round robin scheduling with time slice of one time units is
- (A) 10 (B) 4
 (C) 8 (D) 9

[GATE 1996 : IISc Bangalore]

- Q.31** Assume that the following jobs are to be executed on a single processor system.

Job Id	CPU Burst Time
p	4
q	1
r	8
s	1
t	2

The jobs are assumed to have arrived at time 0^+ and in the order p, q, r, s, t. Calculate the departure time (completion time) for job p if scheduling is round robin with time slice 1.

- (A) 4 (B) 10
 (C) 11 (D) 12

[GATE 1993 : IIT Bombay]

- Q.32** Consider the 3 processes, P1, P2 and P3 shown in the table.

Process	Arrival Time	Time Units Required
P1	0	5
P2	1	7
P3	3	4

The completion order of the 3 processes under the policies FCFS and RR2 (round robin scheduling with CPU quantum of 2 time units) are



- (A) FCFS: P1, P2, P3 RR2: P1, P2, P3
 - (B) FCFS: P1, P3, P2 RR2: P1, P3, P2
 - (C) FCFS: P1, P2, P3 RR2: P1, P3, P2
 - (D) FCFS: P1, P3, P2 RR2: P1, P2, P3

[GATE 2012 : IIT Delhi]

- Q.33** Which scheduling policy is most suitable for time-shared operating systems?

 - (A) Shortest Job First
 - (B) Round Robin
 - (C) First come First serve
 - (D) Elevator

[GATE 1995 : IIT Kanpur]

- Q.34** For the processes listed in the following scheduling schemes will give the lowest turnaround time?

Process	Arrival Time	Processing Time
A	0	3
B	1	6
C	4	4
D	6	2

- (A) First Come First Serve
 - (B) Non- preemptive Shortest Job First
 - (C) Shortest Remaining Time
 - (D) Round Robin with Quantum value two

[GATE 2015 : IIT Kanpur]

- Q.35** If the time-slice used in the round-robin scheduling policy is more than the maximum time required to execute any process, then the policy will

 - (A) degenerate to shortest job first
 - (B) degenerate to priority scheduling
 - (C) degenerate to first come first serve
 - (D) None of the above

[GATE 2008 : IISc Bangalore]

- Q.36** Which of the following statements are true?

 - I. Shortest remaining time first scheduling may cause starvation.
 - II. Preemptive scheduling may cause starvation

- III. Round robin is better than FCFS in terms of response time.

- (A) I only (B) I and III only
(C) II and III only (D) I, II and III

[GATE 2010 : IIT Guwahati]

- Q.37** Three processes A, B and C each execute a loop of 100 iteration. In each iteration of the loop, a process performs a single computation that requires t_c CPU millisecond and then initiates a single I/O operation that lasts for t_{io} millisecond. It is assumed that the computer where the processes execute has sufficient number of I/O devices and the OS of the computer assigns different I/O devices to each process. Also the scheduling overhead of the OS is negligible. The process have the following characteristics:

Process	t_c	t_{i0}
A	100 ms	500 ms
B	350 ms	500 ms
C	200 ms	500 ms

The processes A, B and C are started at times 0,5 and 10 millisecond respectively in a pure time sharing system (round robin scheduling that uses a time slice of 50 milliseconds. The time in millisecond at which process C would complete its first I/O operation is ?

[GATE 2014 : IIT Kharagpur]

- Q.38** The sequence _____ is an optimal non- preemptive scheduling sequence for the following jobs which leaves the CPU idle for _____ unit (s) of time

Job	Arrival Time	Burst Time
1	0.0	9
2	0.6	5
3	1.0	1

- (A) {3, 2, 1}, 1 (B) {2, 1, 3}, 0
 (C) {3, 2, 1}, 0 (D) {1, 2, 3}, 5

[GATE 1995 : IIT Kanpur]

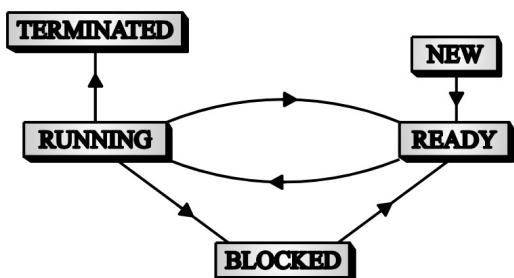


- Q.39** Consider three processes (process id 0, 1, 2 respectively) with compute time bursts 2, 4 and 8 time units. All processes arrive at time zero. Consider the longest remaining time first (LRTF) scheduling algorithm. In LRTF ties are broken by giving priority to the process with the lowest process id. The average turnaround time is:
- (A) 13 units. (B) 14 units.
(C) 15 units. (D) 16 units.
- [GATE 2006 : IIT Kharagpur]**
- Q.40** Which of the following scheduling algorithms is non-preemptive?
- (A) Round Robin
(B) First-In First-out
(C) Multilevel Queue Scheduling
(D) Multilevel Queue Scheduling with Feedback.
- [GATE 2002 : IISc Bangalore]**
- Q.41** Which one of the following statements is/are TRUE?
- (A) Threads of a process share global variables but not heap
(B) The OS does not maintain a separate stack for each thread
(C) ISR is Interrupt Service Routine
(D) Preemptive scheduling may cause starvation
- Q.42** Which of the following is/are the correct definition of a valid process transition in an operating system?
- (A) Wake up: ready \rightarrow running
(B) Dispatch: ready \rightarrow running
(C) Block: ready \rightarrow running
(D) Timer runout: running \rightarrow ready
- Q.43** Three processes arrive at time zero with CPU bursts time of 16, 20 & 10 milliseconds. If the scheduler has prior knowledge about the length of CPU bursts, Minimum achievable average waiting time for these three processes in a non-preemptive scheduler (rounded to nearest integer) is _____ milliseconds.
- [GATE 2021 : IIT Bombay]**
- Q.44** Statements correct in context of CPU scheduling?
- (A) Round Robin policy can be used even when the CPU time required by each of the processes is not known in apriori.
- (B) Implementing preemptive scheduling needs hardware support.
(C) The goal is to only maximize CPU utilization and minimize throughput.
(D) Turnaround time includes waiting time.
- [GATE 2021 : IIT Bombay]**
- Q.45** Which of the following standard C library functions will always invoke a system call when executed from a single-threaded process in a UNIX/LINUX Operating system?
- (A) sleep (B) strlen
(C) malloc (D) exit
- [GATE 2021 : IIT Bombay]**
- Q.46** Which of the following need not necessarily be saved on a context switch between processes?
- (A) General purpose registers
(B) Translation look-aside buffer
(C) Program counter
(D) All of the above
- [GATE 2000 : IIT Kharagpur]**
- Q.47** Which of the following actions is/are typically not performed by the operating system when switching context from process A to process B?
- (A) Saving current register values and restoring saved register values for process B.
(B) Changing address translation tables.
(C) Swapping out the memory image of process A to the disk.
(D) Invalidating the translation look-aside buffer
- Q.48** Consider n processes sharing the CPU in a round-robin fashion. Assuming that each process switch takes s second, what must be the quantum size such that the overhead resulting from process switching is minimized but, at the same time each process is guaranteed to get its turn at the CPU at least every t second?
- (A) $q \leq \frac{t - ns}{n-1}$ (B) $q \geq \frac{t - ns}{n-1}$
(C) $q \leq \frac{t - ns}{n+1}$ (D) $q \geq \frac{t - ns}{n+1}$
- [GATE 1998 : IIT Delhi]**



Practice Questions

- Q.1** What is the degree of multiprogramming?
 (A) the number of processes executed per unit time
 (B) the number of processes in the ready queue
 (C) the number of processes in the I/O queue
 (D) the number of processes in memory
- Q.2** Which one of the following statements is/are TRUE?
 (A) If all processes I/O bound, the ready queue will almost always be empty and the Short term Scheduler will have a little to do.
 (B) If all processes I/O bound, the ready queue will almost always be full and the Short term Scheduler will have a lot to do.
 (C) If all processes CPU bound, the I/O queue will almost always be empty.
 (D) A CPU bound process is one that spends more of its time doing computations.
- Q.3** The process state transition diagram in Figure is representative of



- (A) A batch operating system.
 (B) An operating system with a preemptive scheduler.
 (C) An operating system with a non-preemptive scheduler.
 (D) A uni-programmed operating system.

[GATE 1996 : IISc Bangalore]

- Q.4** A process stack does not contain _____
 (A) Function parameters
 (B) Local variables
 (C) Return addresses
 (D) PID of child process
- Q.5** The address of the next instruction to be executed by the current process is provided by the _____
 (A) CPU registers
 (B) Program counter
 (C) Process stack
 (D) Pipe
- Q.6** Suppose that a process is in “Blocked” state waiting for some I/O service. When the service is completed, it goes to the _____
 (A) Running state (B) Ready state
 (C) Suspended state (D) Terminated state
- Q.7** How does the software trigger an interrupt?
 (A) Sending signals to CPU through bus
 (B) Executing a special operation called system call
 (C) Executing a special program called system program
 (D) Executing a special program called interrupt trigger program
- Q.8** Which one of the following statements is/are TRUE?
 (A) Blocking one kernel level thread blocks all related threads.
 (B) The OS does not maintain a separate stack for each thread
 (C) ISR is Interrupt Service Routine
 (D) Preemptive scheduling may cause starvation
- Q.9** When a process creates a new process two possibilities exists-
 (A) The parent continues to execute concurrently with its children
 (B) The parent stops to execute concurrently with its children
 (C) The parent waits until some or all of its children have terminated



Process	Arrival time	Burst time
P1	0	5
P2	1	3
P3	2	3
P4	4	1

What is average turnaround time for these processes with the pre-emptive shortest remaining processing time first (SRPT) algorithm?

[GATE 2014 : IIT Kharagpur]

- Q.19** Consider the following set of processes, assumed to have arrived at time 0. Consider the CPU scheduling algorithms Shortest Job First (SJF) and Round Robin (RR). For RR, assume that the processes are scheduled in the order P1, P2, P3 P4

Processes	P_1	P_2	P_3	P_4
Burst time (in ms)	8	7	2	4

If the time quantum for RR is 4 ms, then the absolute value of the difference between the average turnaround times (in ms) of SJF and RR (round off to 2 decimal places) is .

[GATE 2020 : IIT Delhi]

- Q.20** Four jobs are waiting to be run. Their expected run times are 6, 3, 5 and x. In what order should they be run to minimize the average response time?

- Q.21** Consider a set of n tasks with known runtimes r_1, r_2, \dots, r_n to be on a uniprocessor machine. Which of the following processor scheduling algorithms will result in the maximum throughput?

- (A) Round-Robin
 - (B) Shortest-job-First
 - (C) Highest-Response-Ratio-Next
 - (D) First-Come-First-Served

[GATE 2001 : IIT Kanpur]

- Q.22** A uni-processor computer system only has two processes, both of which alternate 10 msms CPU bursts with 90 msms I/O bursts. Both the processes were created at nearly the same time. The I/O of both processes can proceed in parallel. Which of the

following scheduling strategies will result in the *least* CPU utilization (over a long period of time) for this system?

- (A) First come first served scheduling
- (B) Shortest remaining time first scheduling
- (C) Static priority scheduling with different priorities for the two processes
- (D) Round robin scheduling with a time quantum of 5 ms.

[GATE 2003 : IIT Madras]

- Q.23** A scheduling algorithm assigns priority proportional to the waiting time of a process. Every process starts with priority zero (the lowest priority). The scheduler re-evaluates the process priorities every T time units and decides the next process to schedule. Which one of the following is TRUE if the processes have no I/O operations and all arrive at time zero?

 - (A) This algorithm is equivalent to the first-come-first-serve algorithm.
 - (B) This algorithm is equivalent to the round-robin algorithm.
 - (C) This algorithm is equivalent to the shortest-job-first algorithm.
 - (D) This algorithm is equivalent to the shortest-remaining-time-first algorithm

[GATE 2013 : IIT Bombay]

- Q.24** The highest-response ratio next scheduling policy favours.....jobs, but it also limits the waiting time ofjobs

[GATE 1999 : IIT Bombay]

- Q.25** Group 1 contains some CPU scheduling algorithms and Group 2 contains some applications. Match entries in Group 1 to entries in Group 2.

Group I **Group II**

- (P) Gang Scheduling (1) Guaranteed Scheduling

(Q) Rate Monotonic Scheduling (2) Real-time Scheduling

(R) Fair Share Scheduling (3) Thread Scheduling

(A) P – 3 Q – 2 R – 1
 (B) P – 1 Q – 2 R – 3
 (C) P – 2 Q – 3 R – 1
 (D) P – 1 Q – 3 R – 2



Classroom Questions

- Q.1** The following two functions P1 and P2 that share a variable B with an initial value of 2 execute concurrently.

P1 ()	P2 ()
{ C = B - 1; B = 2 * C; }	{ D = 2 * B; B = D - 1; }

The number of distinct values that B can possibly take after the execution is _____.

[GATE 2000 : IIT Kharagpur]

- Q.2** Consider three concurrent processes P1, P2 and P3 as shown below, which access a shared variable D that has been initialized to 100

P1	P2	P3
:	:	:
:	:	:
D=D+20	D = D - 50	D = D + 10
:	:	:
:	:	:

The processes are executed on a uniprocessor system running a time - shared operating system .If the minimum and maximum possible values of D after the three process have completed are X of Y respectively, then the value of Y-X is _____.

[GATE 2019 : IIT Madras]

- Q.3** A critical region is:

- (A) One which is enclosed by a pair of P and V operations on semaphores.
- (B) A program segment that has not been proved bug-free.
- (C) A program segment that often causes unexpected system crashes.
- (D) A program segment where shared resources are accessed.

[GATE 1987 : IIT Bombay]

- Q.4** Processes P₁ and P₂ use critical flag in the following routine to achieve mutual exclusion. Assume that critical flag is initialized to FALSE in the main program.

```
get_exclusive_access ()  
{  
if (critical_flag == FALSE) {  
critical_flag = TRUE ;  
critical_region () ;  
critical_flag = FALSE; }  
}
```

Consider the following statements.
i. It is possible for both P₁ and P₂ to access critical region concurrently.
ii. This may lead to a deadlock
Which of the following holds?

- (A) (i) is false and (ii) is true
- (B) Both (i) and (ii) are false
- (C) (i) is true and (ii) is false
- (D) Both (i) and (ii) are true

[GATE 2007 : IIT Kanpur]

- Q.5** Consider the following two-process synchronization solution.

Process 0	Process 1
Entry: loop while (turn == 1); (Critical section) Exit: turn = 1;	Entry: loop while (turn == 0); (Critical section) Exit: turn = 0;

The shared variable turn is initialized to zero. Which one of the following is TRUE?

- (A) This is a correct two- process synchronization solution.
- (B) This solution violates mutual exclusion requirement.
- (C) This solution violates progress requirement.
- (D) This solution violates bounded wait requirement.

[GATE 2016 : IISc Bangalore]

- Q.6** Consider the method used by processes P1 and P2 for accessing their critical sections whenever needed, as given below. The initial values of shared Boolean variables S1 and S2 are randomly assigned.

```
write (S1==S2),
Critical section
S1 = S2;
```

```
write (S1 != S2),
Critical section
S2 = not (S1);
```

Which one of the following statements describes the properties achieved?

- (A) Mutual exclusion but not progress.
- (B) Progress but not mutual exclusion.
- (C) Neither mutual exclusion nor progress
- (D) Both mutual exclusion and progress.

[GATE 2010 : IIT Guwahati]

Q.7 Two processes X and Y need to access a critical section. Consider the following synchronization construct used by both the processes.

Process X /* other code for process X*/	Process Y/* other code for process Y
<pre>while (true){ varP = true; while (varQ == true) { /* Critical Section */ varP = false; }}</pre>	<pre>while (true){ varQ = true; while (varP == true) { /* Critical Section */ varQ = false; }}</pre>

Here, varP and varQ are shared variables and both are initialized to false. Which one of the following statements is true?

- (A) The proposed solution prevents deadlock but fails to guarantee mutual exclusion
- (B) The proposed solution guarantees mutual exclusion but fails to prevent deadlock
- (C) The proposed solution guarantees mutual exclusion and prevents deadlock
- (D) The proposed solution fails to prevent deadlock and fails to guarantee mutual exclusion

[GATE 2010 : IIT Guwahati]

```
/* Process now forks into concurrent
processes P1 & P2 */
```

P1: repeat forever

P2: repeat forever

and-set instruction as follows:

```
void enter _ CS(x)
{
    while (test-and-set(x));
}
void leave _ CS(x)
{
    x=0;
}
```

In the above solution, X is a memory location associated with the CS and is initialized to 0. Now consider the following statements:

- (I) The above solution to CS problem is deadlock-free.
- (II) The solution is starvation free
- (III) The processes enter CS in FIFO order.
- (IV) More than one process can enter CS at the same time.

Which of the above statements are TRUE?

- (A) I only
- (B) I and II
- (C) II and III
- (D) IV only

[GATE 2009 : IIT Roorkee]

Q.9 At a particular time of computation the value of a counting semaphore is 7. Then 20P operations and 15V operations were completed on this semaphore. The resulting value of the semaphore is;

- (A) 42
- (B) 2
- (C) 7
- (D) 12

[GATE 1992 : IIT Delhi]

Q.10 Consider a non-negative counting semaphore S. The operation P(S) decrements S, and V(S) increments S. During an execution, 20 P(S) operations and 12 V(S) operation are issued in some order. The largest initial value of S for which at least one P(S) operation will remain blocked is _____.]

[GATE 2014 : IIT Kharagpur]

Q.11 Given below is a program which when executed spawns two concurrent processes :

```
semaphore X := 0 ;
```

CODE SECTION Q

What does the code achieve?

- (A) It ensures that no process executes CODE SECTION Q before every process has finished CODE

V (X) ; Compute ; P(X) ;	P(X) ; Compute ; V(X) ;
--------------------------------	-------------------------------

Consider the following statements about processes P1 and P2:

- I. It is possible for process P1 to starve.
- II. It is possible for process P2 to starve.

Which of the following holds?

- (A) Both I and II are true
- (B) I is true but II is false
- (C) II is true but I is false
- (D) Both I and II are false

[GATE 2005 : IIT Bombay]

Q.12 A shared variable x, initialized to zero, is operated on by four concurrent processes W, X, Y, Z as follows. Each of the processes W and X reads x from memory, increments by one, stores it to the memory, and then terminates. Each of the processes Y and Z reads x from memory, decrements by two, stores it to memory, and terminates. Each process before reading x invokes the P operation (i.e., wait) on a counting semaphore S and invokes the V operation (i.e., signal) on the semaphore S after storing x to memory. Semaphore S is initialized to two. What is the maximum possible value of x after all processes complete execution?

- (A) -2
- (B) -1
- (C) 1
- (D) 2

[GATE 2013 : IIT Bombay]

Q.13 Each of a set of n processes executes the following code using two semaphores a and b initialized to 1 and 0, respectively. Assume that count is a shared variable initialized to 0 and not used in CODE SECTION P.

CODE SECTION P
 wait (a); count = count + 1;
 if (count == n) signal (b);
 signal (a);
 wait (b); signal (b);

Q.15 Which of the following will always lead to an output starting with 001100110011?

- (A) P(S) at W, V(S) at X, P(T) at Y, V(T) at Z, S and T initially 1
- (B) P(S) at W, V(T) at X, P(T) at Y, V(S) at Z, S initially 1, and T initially 0

SECTION P.

- (B) It ensures that at most two processes are in CODE SECTION Q at any time.
- (C) It ensures that all processes execute CODE SECTION P mutually exclusively.
- (D) It ensures that at most $n-1$ processes are in CODE SECTION P at any time.

[GATE 2020 : IIT Delhi]

Q.14 The following program consists of 3 concurrent processes and 3 binary semaphores. The semaphores are initialized as $S_0 = 1$, $S_1 = 0$, $S_2 = 0$.

Process P0	Process P1	Process P2
<pre>while (true) { wait (S0); print '0'; release (S1); release(S2); }</pre>	<pre>wait (S1); release (S0);</pre>	<pre>wait (S2); release (S0);</pre>

How many times will process P0 print '0'?

- (A) Atleast twice
- (B) Exactly twice
- (C) Exactly thrice
- (D) Exactly once

[GATE 2008 : IISc Bangalore]

Common Data for Questions 15 & 16

Suppose we want to synchronize two concurrent processes P and Q using binary semaphores S and T. The code for the processes P and Q is shown below.

Process P:	Process Q:
<pre>while (1) { W: print '0'; print '0'; X: }</pre>	<pre>while (1) { Y: print '1'; print '1'; Z: }</pre>

Synchronization statements can be inserted only at point W, X, Y and Z.

constraints, what is the minimum number of binary semaphores needed?

- (A) 1
- (B) 2
- (C) 3
- (D) 4

[GATE 2005 : IIT Bombay]

Q.18 Three concurrent processes X, Y and Z

- (C) P(S) at W, V(T) at X, P(T) at Y, V(S) at Z, S and T initially 1
 (D) P(S) at W, V(S) at X, P(T) at Y, V(T) at Z, S initially 1, and T initially 0

[GATE 2003 : IIT Madras]

- Q.16** Which of the following will ensure that the output string never contains a substring of the form 01^n or 10^n where n is odd?
- (A) P(S) at W, V(S) at X, P(T) at Y, V(T) at Z, S and T initially 1
 (B) P(S) at W, V(S) at X, P(T) at Y, V(T) at Z, S and T initially 1
 (C) P(S) at W, V(S) at X, P(S) at Y, V(S) at Z, S initially 1
 (D) V(S) at W, V(T) at X, P(S) at Y, P(T) at Z, S and T initially 1.

[GATE 2003 : IIT Madras]

- Q.17** Two concurrent processes P1 and P2 use four shared resources R1, R2, R3 and R4, as shown below.

P1	P2
Compute: Use R1; Use R2; Use R3; Use R4;	Compute; Use R1; Use R2; Use R3; Use R4;

Both processes are started at the same time, and each resource can be accessed by only one process at a time. The following scheduling constraints exist between the access of resources by the processes:

- P2 must complete use of R1 before P1 gets access to R1
 P1 must complete use of R2 before P2 gets access to R2.
 P2 must complete use of R3 before P1 gets access to R3.
 P1 must complete use of R4 before P2 gets access to R4.

There are no other scheduling constraints between the processes. If only binary semaphores are used to enforce the above scheduling

execute three different code segments that access X executes the P operation (i.e., wait) on semaphores a, b and c; process Y executes the P operation on semaphores b, c and d; process Z executes the P operation on semaphores c, d and a before entering the respective code segments. After completing the execution of its code segment, each process invokes the V operation (i.e., signal) on its three semaphores. All semaphores are binary semaphores initialized to one. Which one of the following represents a deadlock-free order of invoking the P operations by the processes?

- (A) X: P(a)P(b)P(c), Y:P(b)P(c)P(d),
 Z: P(c)P(d)P(a)
 (B) X: P(b)P(a)P(c), Y:P(b)P(c)P(d),
 Z:P(a)P(c)P(d)
 (C) X: P(b)P(a)P(c), Y: P(c)P(b)P(d),
 Z:P(a)P(c)P(d)
 (D) X: P(a)P(b)P(c), Y:P(c)P(b)P(d)
 Z:P(c)P(d)P(a)

[GATE 2013 : IIT Bombay]

- Q.19** The atomic fetch-and-set x, y instruction unconditionally sets the memory location x to 1 and fetches the old value of x in y without allowing any intervening access to the memory location x. Consider the following implementation of P and V function on a binary semaphore S.

```
void P (binary_semaphore * S)
{
    unsigned y;
    unsigned * x = &(S → value);
    do
    {
        fetch-and-set x, y;
    } while (y);
}
void V (binary_semaphore * S)
{
    S → value = 0;
}
```

Which one of the following is true?

- (A) The implementation may not work if context switching is disabled in P
 (B) Instead of using fetch- and- set, a pair of normal load/ store can be used
 (C) The implementation of V is wrong.
 (D) The code does not implement a

P1	P2
while (1) { K; P(mutex); Add an item to the buffer; V(mutex); I ·	while (1) { M; P(mutex); Remove an item from the buffer; V(mutex); N ·

binary semaphore.

[GATE 2006 : IIT Kharagpur]

- Q.20** Consider the following solution to the producer-consumer synchronization problem. The shared buffer size is N . Three semaphores *empty*, *full* and *mutex* are defined with respective initial values of 0, N and 1. Semaphore *empty* denotes the number of available slots in the buffer, for the consumer to read from. Semaphore *full* denotes the number of available slots in the buffer, for the producer to write to. The placeholder variables, denoted by *P*, *Q*, *R*, and *S*, in the code below can be assigned either *empty* or *full*. The valid semaphore operations are: *wait ()* and *signal ()*.

Producer :	Consumer :
do { <i>wait (P);</i> <i>wait (mutex);</i> <i>// Add item to buffer</i> <i>signal (mutex);</i> <i>signal(Q);</i> } while (1);	do { <i>wait (R);</i> <i>wait (mutex);</i> <i>// Consume item from buffer</i> <i>signal (mutex);</i> <i>signal(S);</i> } while (1);

Which one of the following assignments to *P*, *Q*, *R* and *S* will yield the correct solution?

- (A) *P* : full, *Q* : full, *R* : empty, *S* : empty
(B) *P* : empty, *Q* : empty, *R* : full, *S* : full
(C) *P* : full, *Q* : empty, *R* : empty, *S* : full
(D) *P* : empty, *Q* : full, *R* : full, *S* : empty

[GATE 2018 : IIT Guwahati]

- Q.21** The semaphore variables *full*, *empty* and *mutex* are initialized to 0, n and 1, respectively. Process *P1* repeatedly adds one item at a time to a buffer of size n , and process *P2* repeatedly removes one item at a time from the same buffer using the programs given below. In the programs, *K*, *L*, *M* and *N* are unspecified statements.

{ } }

The statements *K*, *L*, *M* and *N* are respectively

- (A) *P(full)*, *V(empty)*, *P(full)*, *V(empty)*
(B) *P(full)*, *V(empty)*, *P(empty)*, *V(full)*
(C) *P(empty)*, *V(full)*, *P(empty)*, *V(full)*
(D) *P(empty)*, *V(full)*, *P(full)*, *V(empty)*

[GATE 2004 : IIT Delhi]

- Q.22** Consider the procedure below for the producer-Consumer problem which uses semaphores:

Semaphore *n* = 0;
Semaphore *s* = 1;

void producer () { while (true){ produce (); semWait (<i>s</i>); addToBuffer (); semSignal (<i>s</i>); semSignal (<i>n</i>); } }	void consumer () { while (true){ semWait (<i>s</i>); semWait (<i>n</i> '); remove FromBuffer (); semSignal (<i>s</i>); consume (); } }
---	--

Which one of the following is **TRUE**?

- (A) The producer will be able to add an item to the buffer, but the consumer can never consume it.
(B) The consumer will remove no more than one item from the buffer.
(C) Deadlock occurs if the consumer succeeds in acquiring semaphore *s* when the buffer is empty.
(D) The starting value for the semaphore *n* must be 1 and not 0 for deadlock-free operation.

[GATE 2014 : IIT Kharagpur]

- Q.23** A solution to the Dining Philosophers Problem which avoids deadlock is

- (A) Ensure that all philosophers pick up the left fork before the right fork.
(B) Ensure that all philosophers pick up the right fork before the left fork.

- (C) Ensure that one particular philosopher picks up the left fork before the right fork, and that all other philosophers pick up the right fork before the left fork.
(D) None of the above.

[GATE 2014 : IIT Kharagpur]

- Q.24** Let $m[0].....m[4]$ be mutexes (binary semaphores) and $P[0].....P[4]$

$P_0.....P_{n-1}$. In the code, function *pmax* returns an integer not smaller than any of its arguments. For all i , $t[i]$ is initialized to zero.

Code for *P1*

```
do {  
    c[i]= 1;  
    t[i]= pmax(t[0],.....,t[n-1])+1; c[i]=0  
    for every  $j \neq i$  in  $\{0, \dots, n-1\}$ 
```


- (B) The value of counter is 1 after all the threads successfully complete the execution of parop.
- (C) There is a deadlock involving all the threads.
- (D) The value of counter is 5 after all the threads successfully complete the execution of parop.

[GATE 2021 : IIT Bombay]

- Q.29** Consider a computer system with multiple shared resource types, with one instance per resource type. Each instance can be owned by only one process at a time. Owning and freeing of resources are done by holding a global lock (L). The following scheme is used to own a resource instance:

```

function OWNRESOURCE (Resource R)
    Acquire lock L // a global lock
    if R is available then
        Acquire R
        Release lock L
    else
        if R is owned by another process P
        then
            Terminate P, after releasing all
            resources owned by P
            Acquire R
            Restart P
            Release lock L
            end if
            end if
        end function
    
```

Which of the following choice(s) about the above scheme is/are correct?

- (A) The scheme ensures that deadlocks will not occur.
- (B) The scheme violates the mutual exclusion property.
- (C) The scheme may lead to live-lock.
- (D) The scheme may lead to starvation.

[GATE 2021 : IIT Bombay]

barrier with line numbers shown on the left.
void barrier (void){

```

1.    P(S);
2.    process _arrived++;
3.    V(S);
4.    while (process _arrived! = 3)
5.    P(S);
6.    process _left++;
7.    if(process_left==3) {
8.        process _arrived =0;
9.        process_left=0;
10.    }
11.    V(S);
}
    
```

The variables process _arrived and process _left are shared among all processes and are initialized to zero. In a concurrent program all the three processes call the barrier function when they need to synchronize globally.

- Q.30** The above implementation of barrier is incorrect. Which one of the following is true?

- (A) The barrier implementation is wrong due to the use of binary semaphore S
- (B) The barrier implementation may lead to a deadlock if two barrier invocation are used in immediate succession
- (C) Lines 6 to 10 need not be inside a critical section.
- (D) The barrier implementation is correct if there are only two processes instead of three.

[GATE 2006 : IIT Kharagpur]

- Q.31** Which one of the following rectifies the problem in the implementation?

- (A) Lines 6 to 10 are simply replaced by process _arrived
- (B) At the beginning of the barrier the first process to enter the barrier

 waits until process arrived becomes zero before proceeding to execute P(S)

- (C) Context switch is disabled at the beginning of the barrier and re-enabled at the end.
- (D) The variable process _left is made private instead of shared.

[GATE 2006 : IIT Kharagpur]

- Q.32** The P and V operations on counting semaphores, where s is a counting semaphore are defined as follows:

- (A) 0 and 0
- (B) 0 and 1
- (C) 1 and 0
- (D) 1 and 1

[GATE 2008 : IISc Bangalore]

- Q.33** Consider the following solution to the producer-consumer problem using a buffer of size 1. Assume that the initial value of account is 0. Also assume that the testing of count and assignment to count are atomic operations.

[GATE 1999 : IIT Bombay]

Show that in this solution it is possible that both the processes are

$P(s)$: $s = s - 1$;
If $s < 0$ then wait;
 $V(s)$: $s = s + 1$;
If $s \leq 0$ then wake up a process waiting
on s ;

Assume that P_b and V_b the wait and
signal operations on binary semaphores
 X_b and Y_b are used to implement the
semaphore operations $P(s)$ and $V(s)$ as
follows :

P(s): $P_b(x_b);$	V(s): $P_b(x_b);$ $s = s + 1;$ if ($s \leq 0$) $V_b(y_b);$ $V_b(x_b);$
$s = s - 1;$ if ($s < 0$) { $V_b(x_b);$ $P_b(y_b);$ } else $V_b(x_b);$	

The initial values of x_b and y_b are respectively

sleeping at the same time.

Producer:	Consumer:
Repeat	Repeat
Produce an item;	
if count = 1 then sleep;	if count = 0 then sleep;
place item in buffer.	
count = 1;	Remove item from buffer;
Wakeup(Consumer);	count = 0;
Forever	Wakeup(Producer);
	Consume item;
	Forever;

Practice Questions

- Q.1** A critical section is a program segment.

 - (A) Which should run in certain specified amount of time
 - (B) Which avoids resources are accessed
 - (C) Where shared resources are accessed
 - (D) Which must be enclosed by a pair of semaphore operations, P and V

[GATE 1996 : IISc Bangalore]

- Q.2** When several processes access the same data concurrently and the outcome of the execution depends on the particular order in which the access takes place is called _____

(A) dynamic condition
(B) race condition

90

- Q.5** Consider Peterson's algorithm for mutual exclusion between two concurrent processes i and j. The program executed by process i is shown below.

```
Repeat
  flag [i] = true;
  turn = j;
  while (P) do no-op;
Enter critical section, perform actions,
Then exit critical section
  flag [i] = false;
Perform other non- critical section
action.
  until false;
```

- (C) essential condition
(D) critical condition

[GATE 1996 : IISc Bangalore]

Q.3 Mutual exclusion can be provided by the _____
(A) mutex locks
(B) binary semaphores
(C) Semaphore only
(D) Spin lock

[GATE 1996 : IISc Bangalore]

Q.4 Process synchronization can be done on _____
(A) hardware level
(B) software level
(C) both hardware and software level
(D) none of the mentioned

this semaphore. The resulting value of the semaphore is .

[GATE 1998 : IIT Delhi]

For the program to guarantee mutual exclusion, the predicate P in the while loop should be

- (A) flag [j] = true and turn = i
- (B) flag [j] = true and turn = j
- (C) flag [i] = true and turn = j
- (D) flag [i] = true and turn = i

[GATE 2001 : IIT Kanpur]

- Q.6** Two processes, P1 and P2, need to access a critical section of code. Consider the following synchronization construct used by the processes: Here, wants1 and wants2 are shared variables, which are initialized to false. Which one of the following statements is TRUE about the above construct?

/* P1 */	/* P2 */
<pre>while (true) { wants1 = true; while (wants2 == true); /* Critical Section */ wants1=false; } /* Remainder section */</pre>	<pre>while (true) { wants2 = true; while (wants1==true); /* Critical Section */ wants2 = false; } /* Remainder section */</pre>

- (A) It does not ensure mutual exclusion.
- (B) It does not ensure bounded waiting.
- (C) It requires that processes enter the critical section in strict alternation.
- (D) It does not prevent deadlocks, but ensures mutual exclusion.

[GATE 2007 : IIT Kanpur]

- Q.7** A Counting semaphore was initialized to 10. Then 6P (Wait) operations and 4V (Signal) operations were completed on

P₁:
where true do{
L₁:
L₂:
X = X + 1;
Y = Y - 1:
V(S_X);
V(S_Y);
}

P₂:
where true do
{
L₃:
L₄:
Y = Y + 1;
X = X - 1:
V(S_Y);
V(S_X);
}

In order to avoid deadlock, the operators at L₁, L₂, L₃ and L₄ are respectively .

- (A) P(S_Y),P(S_X);P(S_X),P(S_Y)
- (B) P(S_X),P(S_Y);P(S_Y),P(S_X)
- (C) P(S_X),P(S_X);P(S_Y),P(S_Y)
- (D) P(S_X),P(S_Y);P(S_X),P(S_Y)

Q.9

Select the correct statements regarding mutex lock to prevent race condition:

- (A) A process must acquire the lock before entering a critical section
- (B) A process need not acquire the lock before entering a critical section;
- (C) It releases the lock when it exits the critical section;
- (D) A process must acquire the lock when it exits the critical section

[GATE 2004 : IIT Delhi]



- Q.10** A certain computation generates two arrays a and b such that $a[i] = f(i)$ for $0 \leq i < n$ and $b[i] = g(a[i])$ for $0 \leq i < n$. Suppose this computation is decomposed into two concurrent processes X and Y such that X computes the array a and Y computes the array b. The processes employ two binary semaphores R and S, both initialized to zero. The array a is shared by the processes are shown below.

Process X:	Process Y:
<pre>private i; for(i=0;i<n; i++) { ...</pre>	<pre>private i; for(i = 0; i<n; i++) { ...</pre>

AcquireLock(L)
{
while (Fetch _ And _Add (L,1))
L = 1;
}
ReleaseLock(L)
{
L = 0;
}

This implementation

- (A) fails as L can overflow
- (B) fails as L can take on a non-zero value when the lock is actually available
- (C) work correctly but may starve some processes

<code>a[i] = r(i);</code>	<code>entry Y (R,S);</code>
<code>exit X (R,S);</code>	<code>b[i] = g(a[i]);</code>
}	

Which one of the following represents the CORRECT implementation of Exit X and Entry Y?

(A) <code>ExitX(R, S) { P(R); V(S); }</code>	(B) <code>ExitX(R, S) { V(R); V(S); }</code>
<code>EntryY (R, S) { P(S); V(R); }</code>	<code>EntryY(R, S) { P(R); P(S); }</code>
(C) <code>ExitX(R, S) { P(S); V(R); }</code>	(D) <code>ExitX(R, S) { V(R); P(S); }</code>
<code>EntryY(R, S) { V(S); P(R); }</code>	<code>EntryY(R, S) { V(S); P(R); }</code>

[GATE 2013 : IIT Bombay]

- Q.11** Fetch _And _Add (X, i) is an atomic Read- Modify- write instruction that reads the value of memory location X, increments it by the value 1 and returns the old value of X. It is used in the pseudo code shown below to implement a busy- wait lock. L is an unsigned integer shared variable initialized to 0. The value of 0 corresponds to lock being available, while any non-zero value corresponds to the lock being not available.

(D) works correctly without starvation

[GATE 2012 : IIT Delhi]

- Q.12** Consider the following two-process synchronization solution

Process 0 Entry: loop while (turn == 1); (critical section) Exit: turn = 1;

Process 1 Entry: loop while (turn == 0); (critical section) Exit: turn = 0;

The shared variable turn is initialized to zero. Which one of the following is TRUE?

- (A) This is a correct two-process synchronization solution.
- (B) This solution violates mutual exclusion requirement.
- (C) This solution violates progress requirement.
- (D) This solution violates bounded wait requirement.

[GATE 2016 : IISc Bangalore]

- Q.13** Fill in the boxes below to get a solution for the readers-writers problem, using a single binary semaphore, mutex (initialized to 1) and busy waiting. Write the box numbers (1, 2 and 3), and their contents in your answer book.

L1	L2
<pre>int R = 0, W = 0; Reader () { wait (mutex); if (W == 0) { R = R + 1; _____(1) } }</pre>	<pre>Writer () { wait (mutex); if (W == 0) { signal (mutex); goto L2; } W=1;</pre>

<code>}</code>	<code>signal (mutex);</code>
<code>else {</code>	<code>...../*do the write*/</code>
<code> _____ (2)</code>	<code>wait(mutex);</code>
<code> goto L1;</code>	<code>W=0;</code>
<code>}</code>	<code>signal (mutex);</code>
<code>..../* do the</code>	
<code>read*/</code>	
<code> wait (mutex);</code>	
<code> R = R - 1;</code>	
<code> signal (mutex);</code>	

3) Deadlock



Classroom Questions

[GATE 1997 : IIT Madras]

- Q.2** A Computer system has 6 tape drives, with n processes competing for them. Each process may need 3 tape drives. The maximum value of n for which the

preemptive resource allocation policy is used. At any given instance, a request is not entertained if it cannot be completely satisfied. Three process P1, P2, P3 request the resources as follows if executed independently.

Process	Process P2:	Process P3:
P1: t = 0 : requests 2 units of R2	t = 0 : requests 2 units of R3	t = 0 : requests 1 unit of R4
	t = 2 : requests 1	t = 2 : requests 2

The maximum value of n for which the system is guaranteed to be deadlock free is

[GATE 1992 : IIT Delhi]

Q.3 Consider a system having m resources of the same type. These resources are shared by 3 processes A, B and C, which have peak demands of 3, 4 and 6 respectively. For what value of m deadlock will not occur?

[GATE 1993 : IIT Bombay]

Q.4 A system has 6 identical resources and N processes competing for them. Each process can request atmost 2 resources. Which one of the following values of N could lead to a deadlock?

[GATE 2015 : IIT Kanpur]

Q.5 Consider a system with 3 processes that share 4 instances of the same resource type. Each process can request a maximum of K instances. Resource instances can be requested and released only one at a time. The largest value of K that will always avoid deadlock is _____.

[GATE 2018 : IIT Guwahati]

Q.6 Consider a system with 4 types of resources R1 (3 units), R2 (2 units), R3 (3 units), R4 (2 units). A non-

t = 1 :	unit of R4	unit of R1
requests 1 unit of R3	t = 4 : request 1 unit of R1	t = 5 : releases 2 units of R1
t = 3 : request 2 units of R1	t = 6 : releases 1 unit of R3	t = 7 : requests 1 unit of R2
t = 5 : releases 1 unit of R2 and 1 unit of R1	t = 8 : finishes	t = 8 : requests 1 units of R3
t = 7 : releases 1 unit of R3		t = 9 : Finishes
t = 8 : requests 2 units of r4		
t = 10 : finishes		

Which one of the following statements is **TRUE** if all three processes run concurrently starting at time $t = 0$?

- (A) All processes will finish without any deadlock
 - (B) Only P1 and P2 will be in deadlock
 - (C) Only p1 and P3 will be in deadlock
 - (D) All three processes will be in deadlock

[GATE 2009 : IIT Roorkee]

Q.7 An operating system implements a policy that requires a process to release all resources before making a request for another resource. Select the TRUE statement from the following:

- (A) Both starvation and deadlock can occur
 - (B) Starvation can occur but deadlock cannot occur
 - (C) Starvation cannot occur but deadlock can occur
 - (D) Neither starvation nor deadlock can occur

[GATE 2008 : IISc Bangalore]

Q.8 Consider the following policies for preventing deadlock in a system with mutually exclusive resources.

- I. Processes should acquire all their resources at the beginning of execution. If any resource acquired

(D) Request and all required resources allocated before execution

[GATE 2000 : IIT Kharagpur]

Q.10 Suppose n processes, p_1, \dots, p_n share m identical resource units, which can be reserved and released on at time. The maximum resource requirement of process p_i is s_i where $s_i > 0$. Which one of the following is a sufficient condition for ensuring that deadlock does not occur?

- (A) $\forall i, s_i < m$ (B) $\forall i, s_i < n$
 (C) $\sum_{i=1}^n s_i < (m+n)$ (D) $\sum_{i=1}^n s_i < (m \times n)$

[GATE 2005 : IIT Bombay]

Consider the following snapshot of a system running n processes. Process i is holding x_i instances of a resource R, for $1 \leq i \leq n$. Currently all instances of

- so far are released.
- The resources are numbered uniquely, and processes are allowed to request for resources only in increasing resource numbers.
 - The resources are numbered uniquely, and processes are allowed to request for resources only in decreasing resource numbers.
 - The resources are numbered uniquely, a process is allowed to request only for a resource with resource number larger than its currently held resources.

Which of the above policies can be used for preventing deadlock?

- Any one of I and III but not II or IV
- Any one of I, III, and IV but not II
- Any one of II and III but not I or IV
- Any one of I, II, III, and IV

[GATE 2015 : IIT Kanpur]

Q.9 Which of the following is NOT a valid deadlock prevention scheme?

- Release all resources before requesting a new resource
- Number the resources uniquely and never request a lower numbered resource than the last one requested.
- Never request a resource after releasing any resource.

R are occupied. Further, for all i , process I has placed a request for an additional y_i instances while holding the x_i instances it already has. There are exactly two processes P and q such that $y_p = y_q = 0$.

Which one of the following conditions guarantees that no other process apart from p and q can complete execution?

- $X_p + X_q < \text{Min } \{Y_k : 1 \leq k \leq n, k \neq p, k \neq q\}$
- $\text{Min } \{X_p, X_q\} \geq \text{Min } \{Y_k : 1 \leq k \leq n, k \neq p, k \neq q\}$
- $\text{Min } \{X_p, X_q\} \leq \text{Max } \{Y_k : 1 \leq k \leq n, k \neq p, k \neq q\}$
- $X_p + X_q < \text{Max } \{Y_k : 1 \leq k \leq n, k \neq p, k \neq q\}$

[GATE 2019 : IIT Madras]

Q.12 A system has n resources R_0, R_1, \dots, R_{n-1} , and K processes P_0, P_1, \dots, P_{k-1} . The implementation of the resource request logic of each process P_i is as follows:

```
if (i%2==0)
{
    if (i<n) request  $R_i$ ;
    if (i+2<n) request  $R_{i+2}$ ;
}
else
{
```

```
if (i<n) request  $R_{n-1}$ ;
if (i+2<n) request  $R_{n-i-2}$ ;
}
```

In which one of the following situations is a deadlock possible?

- $n = 40, k = 26$
- $n = 21, k = 12$
- $n = 20, k = 10$
- $n = 41, k = 9$

[GATE 2010 : IIT Guwahati]

Q.13 A system shares 9 tape drives. The current allocation and maximum requirement of allocation and maximum requirement of tape drives for three processes are shown below:

Process	Current Allocation	Maximum Requirement
P1	3	7
P2	1	6
P3	3	5

Which of the following best describes current state of the system?

REQ1: P0 requests 0 units of X, 0 units of Y and 2 units of Z

REQ2: P1 requests 2 units of X, 0 units of Y and 0 units of Z

Which one of the following is **TRUE**?

- Only REQ1 can be permitted.
- Only REQ2 can be permitted.
- Both REQ1 and REQ2 can be permitted.
- Neither REQ1 nor REQ2 can be permitted.

[GATE 2014 : IIT Kharagpur]

Q.15 In a system, there are three types of resources : E, F and G. Four processes P_0, P_1, P_2 and P_3 execute concurrently. At the outset, the processes have declared their maximum resource requirements using a matrix named Max as given below. For example, $\text{Max}[P_2, F]$ is the maximum number of instances of F that P_2 would require.

- (A) Sate, Deadlocked
 - (B) Sate, Not Deadlocked
 - (C) Not Sate, Deadlocked
 - (D) Not Sate, Not Deadlocked

[GATE 2017 : IIT Roorkee]

- Q.14** An operating system uses the Banker's algorithm for deadlock avoidance when managing the allocation of three resource types X, Y, and Z to three processes P0, P1, and P2. The table given below presents the current system state. Here, the allocation matrix shows the current number of resources of each type allocated to each process and the max matrix shows the maximum number of resources of each type required by each process during its execution.

	Allocation			Max		
	X	Y	Z	X	Y	Z
P0	0	0	1	8	4	3
P1	3	2	1	6	2	0
P2	2	1	1	3	3	3

There are 3 units of X, 2 units of type Y and 2 units of type Z still available. The system is currently in a safe state. Consider the following independent requests for additional resources in the current state:

The number of instances of the resources allocated to the various processes at any given state is given by a matrix named Allocation.

Consider a state of the system with the Allocation matrix as shown below, and in which 3 instances of E and 3 instances of F are the only resources available.

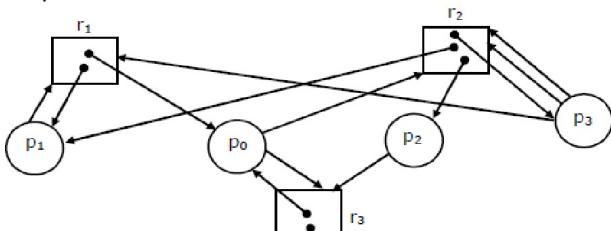
Allocation				Max			
	E	F	G		E	F	G
P_0	1	0	1	P_0	4	3	1
P_1	1	1	2	P_1	2	1	4
P_2	1	0	3	P_2	1	3	3
P_3	2	0	0	P_3	5	4	1

From the perspective of deadlock avoidance, which one of the following is true?

- (A) The system is in *safe* state.
 - (B) The system is not in *safe* state, but would be *safe* if one more instance of E were available
 - (C) The system is not in *safe* state, but would be *safe* if one more instance of F were available
 - (D) The system is not in *safe* state, but would be *safe* if one more instance of G were available

[GATE 2018 : IIT Guwahati]

- Q.16** Consider the resource allocation graph given in the figure. Which of these processes will finish LAST?



- (A) P0
 - (B) P3
 - (C) P2
 - (D) None of the above, the system is in deadlock state.

[GATE 1994 : IIT Kharagpur]

Practice Questions

- Q.2** A system contains three programs and each requires three tape units for its operation. The minimum number of tape units required is _____.

- (B) using thread
 - (C) using pipes
 - (D) all of the mentioned

[GATE 2008 : IISc Bangalore]

- Q.6** A single processor system has three resource types X, Y, and Z which are shared by three processes. There are 5 units of each resource type. Consider the following scenario, where the column alloc denotes the number of units of each resource type allocated to

tape units which the system must have such that deadlocks never arise is _____.

[GATE 2014 : IIT Kharagpur]

- Q.3** A system is having 10 user processes P1, P2, P3 . . . P10 where P1 requires 2 units of resource R, P2 requires 3 units of resource R, P3 requires 4 units of resource R and so on. The minimum number of units of R that ensures no deadlock is _____.

- Q.4** Which of the following is **NOT** true of deadlock prevention and deadlock avoidance schemes?

- (A) In deadlock prevention, the request for resources is always granted if the resulting state is safe
- (B) In deadlock avoidance, the request for resources is always granted if the resulting state is safe
- (C) Deadlock avoidance is less restrictive than deadlock prevention.
- (D) Deadlock avoidance requires knowledge of resource requirements a priori.

[GATE 2008 : IISc Bangalore]

- Q.5** The circular wait condition can be prevented by _____.

- (A) defining a linear ordering of resource types

each process, and the column request denotes the number of units of each resource type requested by a process in order to complete execution. Which of these processes will finish last?

	Alloc			request		
	X	Y	Z	X	Y	Z
P0	1	2	1	1	0	3
P1	2	0	1	0	1	2
P2	2	2	1	1	2	0

- (A) P0
- (B) P1
- (C) P2
- (D) None of the above, since system is in a deadlock

[GATE 2005 : IIT Bombay]

- Q.7** Which of the following phenomena are responsible for deadlock?

- (A) A process holding at least one resource is waiting to acquire additional resources held by other processes.
- (B) Only one process at a time can use a resource.
- (C) A resource can be released only voluntarily by the process holding it, after that process has completed its task.
- (D) All of the above

[GATE 2005 : IIT Bombay]



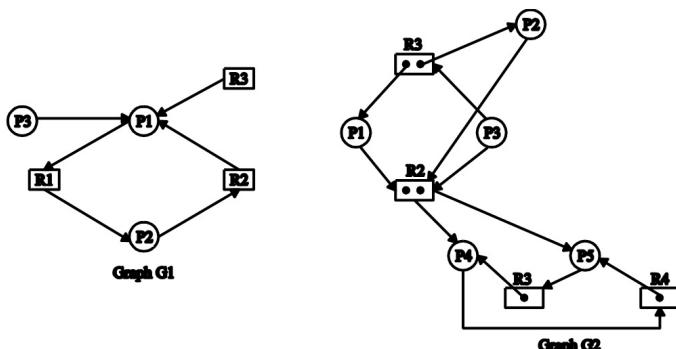
- Q.8** Match the following columns while considering the case of deadlock prevention.

I.	Mutual Exclusion	P.	Low resource utilization and possibility of starvation
II.	Hold and wait	Q.	Not practical for most systems
III.	No preemption	S.	Must hold for non-sharable resources, thus can't be used for deadlock prevention

- (A) I-S, II-Q, III-P
- (B) I-Q, II-S, III-P
- (C) I-S, II-P, III-Q
- (D) None of the above

[GATE 2005 : IIT Bombay]

- Q.9** Consider the resource allocation graphs G1 and G2. What can be said about deadlock condition?



- (A) Both are deadlocked
- (B) G1 deadlocked, G2 not
- (C) G1 not, G2 deadlocked
- (D) None is deadlocked

[GATE 2005 : IIT Bombay]

4**Memory Management and Virtual Memory****Classroom Questions**

- Q.1** Consider the following heap (in given figure) in which blank regions are not in use and hatched regions are in use.

◀ 50 ▶ 150 ▶ 300 ▶ 350 ▶ 600 ▶



The sequence of requests for blocks of sizes 300, 25, 125, 50 can be satisfied if we use:

- (A) Either first fit or best fit policy (any one)
- (B) First fit but not best fit policy
- (C) Best fit but not first fit policy
- (D) None of the above

[GATE 1994 : IIT Kharagpur]

- Q.2** Consider six memory partitions of sizes 200 KB, 400 KB, 600 KB, 500 KB, 300 KB and 250 KB where KB refers to

J_6	10k	1
J_7	7k	8
J_8	20k	6

The time at which the request for J_7 will be completed will be

- (A) 16
- (B) 19
- (C) 20
- (D) 37

[GATE 2007 : IIT Kanpur]

- Q.4** Consider allocation of memory to a new process. Assume that none of the existing holes in the memory will exactly fit the process's memory requirement. Hence, a new hole of smaller size will be created if allocation is made in any of the existing holes. Which one of the following statement is TRUE?

- (A) The hole created by first fit is

and 200 KB, where KB refers to kilobyte. These partitions need to be allotted to four processes of size 357 KB, 210 KB, 468 KB and 491 KB in that order. If the best fit algorithm is used, which partitions are NOT allotted to any process?

- (A) 200 KB and 300 KB
- (B) 200 KB and 250 KB
- (C) 250 KB and 300 KB
- (D) 300 KB and 400 KB

[GATE 2015 : IIT Kanpur]

- Q.3** Let a memory have four free blocks of sizes 4k, 8k, 20k, 2k. These blocks are allocated following the best-fit strategy. The allocation requests are stored in a queue as shown below.

Request No	Request sizes	Usage Time
J_1	2k	4
J_2	14k	10
J_3	3k	2
J_4	6k	8
J_5	6k	4

(A) The hole created by first fit is always larger than the hole created by next fit.

- (B) The hole created by worst fit is always larger than the hole created by first fit.
- (C) The hole created by best fit is never larger than the hole created by first fit.
- (D) The hole created by next fit is never larger than the hole created by best fit.

[GATE 2020 : IIT Delhi]

- Q.5** Consider a system with byte-addressable memory, 32-bit logical addresses, 4 kilobyte page size and page table entries of 4 bytes each. The size of the page table in the system in megabytes is _____.

- Q.6** Consider a machine with 64 MB physical memory and a 32-bit virtual address space. If the page size is 4KB, what is the approximate size of the page table?

- 
- (A) 16 M
 - (B) 8 MB
 - (C) 2MB
 - (D) 24MB

[GATE 2001 : IIT Kanpur]

- Q.7** In a virtual memory system, size of virtual address is 32-bit, size of physical address is 30-bit, page size is 4 Kbyte and size of each page table entry is 32-bit. The main memory is byte addressable. Which one of the following is the maximum number of bits that can be used for storing protection and other information in each page table entry?

- (A) 2
- (B) 10
- (C) 12
- (D) 14

[GATE 2004 : IIT Delhi]

- Q.8** Consider a computer system with 40-bit virtual addressing and page size of sixteen kilobytes. If the computer system has a one-level page table per process and each page table entry requires 48 bits, then the size of the per-process page table is _____ megabytes.

[GATE 2016 : IISc Bangalore]

- Q.9** Let the page fault service time be 10ms in a computer with average memory

one in every 10,000 instruction. What is the effective average instruction execution time?

- (A) 645 nanoseconds
- (B) 1050 nanoseconds
- (C) 1251 nanoseconds
- (D) 1230 nanoseconds

[GATE 2004 : IIT Delhi]

- Q.12** A CPU generates 32-bit virtual addresses. The page size is 4 KB. The processor has a translation look-aside buffer (TLB) which can hold a total of 128 page table entries and is 4-way set associative. The minimum size of the TLB tag is:

- (A) 11 bits
- (B) 13 bits
- (C) 15 bits
- (D) 20 bits

[GATE 2006 : IIT Kharagpur]

- Q.13** A computer system implements a 40 bit virtual address, page size of 8 kilobytes, and a 128-entry translation look-aside buffer (TLB) organized into 32 sets each having four ways. Assume that the TLB tag does not store any process id. The minimum length of the TLB tag in bits is _____.

in a computer with average memory access time being 20ns. If one page fault is generated for every 10^6 memory accesses, what is the effective access time for the memory?

- (A) 21ns (B) 30ns
(C) 23ns (D) 35ns

[GATE 2011 : IIT Madras]

Q.10 If an instruction takes i microseconds and a page fault takes an additional j microseconds, the effective instruction time if on the average a page fault occurs every k instruction is _____.

- (A) $i + (j/k)$ (B) $i + j*k$
(C) $(i + j) / k$ (D) $(i + j) *k$

[GATE 1998 : IIT Delhi]

Q.11 Consider a system with a two-level paging scheme in which a regular memory access takes 150 nanoseconds and servicing a page fault takes 8 millisecond. An average instruction takes 100 nanoseconds of CPU time and two memory accesses. The TLB hit ratio is 90 % and the page fault rate is

100

- (A) 20 (B) 10
(C) 11 (D) 22

[GATE 2015 : IIT Kanpur]

Q.14 Consider a process executing on an operating system that uses demand paging. The average time for a memory access in the system is M units if the corresponding memory page is available in memory, and D units if the memory access causes a page fault. It has been experimental measured that the average time taken for a memory access in the process is X units.

Which one of the following is the correct expression for the page fault rate experienced by the process?

- (A) $(D - M) / (X - M)$
(B) $(X - M) / (D - M)$
(C) $(D - X) / (D - M)$
(D) $(X - M) / (D - X)$

[GATE 2018 : IIT Guwahati]

Q.15 A demand paging system takes 100 time units to service a page fault and

Operating System

300 time units to replace a dirty page. Memory access time is 1 time unit. The probability of a page fault is p . In case of a page fault, the probability of page being dirty is also p . It is observed that the average access time is 3 time units. Then the value of p is

- (A) 0.194 (B) 0.233
(C) 0.514 (D) 0.981

[GATE 2007 : IIT Kanpur]

Q.16 Assume that in a certain computer, the virtual addresses are 64 bits long and the physical addresses are 48 bits long. The memory is word addressable. The page size is 8k and the word size is 4 bytes. The Translation Look-aside Buffer (TLB) in the address translation path has 128 valid entries. At most how many distinct virtual addresses can be translated without any TLB miss?

- (A) 16×2^{10} (B) 8×2^{20}
(C) 4×2^{20} (D) 256×2^{10}

[GATE 2019 : IIT Madras]

Q.17 Consider a paging system that uses 1-level page table residing in main memory and a TLB for address translation. Each main memory access takes 100 ns and TLB lookup takes 20

10 bits are used as index into the second level page table.

The 12 least significant bits of the virtual address are used as offset within the page. Assume that the page table entries in both levels of page tables are 4 bytes wide. Further, the processor has a translation look-aside buffer (TLB), with a hit rate of 96%. The TLB caches recently used virtual page number and the corresponding physical page numbers. The processor also has a physically address cache with a hit rate of 90%. Main memory access time is 10 ns, cache access time 1 ns, and TLB access time also 10 ns.

Assuming that no page faults occur, the average time taken to access a virtual address is approximately (to the nearest 0.5 ns)

- (A) 1.5 ns (B) 2 ns
(C) 3 ns (D) 4 ns

[GATE 2003 : IIT Madras]

Q.19 Consider the virtual page reference string

1, 2, 3, 2, 4, 1, 3, 2, 4, 1

On a demand paged virtual memory system running on a computer system

ns. Each page transfer to/from the disk takes 5000 ns. Assume that the TLB hit ratio is 95%, page fault rate is 10%. Assume that for 20% of the total page faults, a dirty page has to be written back to disk before the required page is read from disk. TLB update time is negligible.

The average memory access time in ns (round off to 1 decimal places) is

[GATE 2020 : IIT Delhi]

- Q.18** A processor uses 2- level page table for virtual to physical address translation. Page tables for both levels are stored in the main memory. Virtual and physical address are both 32 bits wide. The memory is byte addressable. For virtual to physical address translation, the 10 most significant bits for the virtual address are used as index into the first level page table while the next

that has main memory size of 3 pages frames which are initially empty. Let LRU, FIFO and under the corresponding page replacement policy. Then

- (A) OPTIMAL < LRU < FIFO
 - (B) OPTIMAL < FIFO < LRU
 - (C) OPTIMAL = LRU
 - (D) OPTIMAL = FIFO

[GATE 2012 : IIT Delhi]

- Q.20** Consider a main memory with five page frames and the following sequence of page references: 3, 8, 2, 3, 9, 1, 6, 3, 8, 9, 3, 6, 2, 1, 3. which one of the following is true with respect to page replacement policies First in First out (FIFO) and Least Recently Used (LRU)?

 - (A) Both incur the same number of page fault
 - (B) FIFO incurs 2 more page fault than LRU
 - (C) LRU incurs 2 more page faults than FIFO



- (D) FIFO incurs 1 more page faults than LRU

[GATE 2015 : IIT Kanpur]

[GATE 2010 : IIT Guwahati]

[GATE 1995 : IIT Kanpur]

- Q.23** The address sequence generated by tracing a particular program executing in a pure demand paging system with 100 bytes per page is 0100, 0200, 0430, 0499, 0510, 0530, 0560, 0120, 0220, 0240, 0260, 0280, 0410.

main memory at the end of the sequence?

- (A) 6 and 1, 2, 3, 4
 - (B) 7 and 1, 2, 4, 5
 - (C) 8 and 1, 2, 4, 5
 - (D) 9 and 1, 2, 3, 5

[GATE 2008 : IISc Bangalore]

- Q.25** Which page replacement policy sometimes leads to more page faults when size of memory is increased?

- (A) Optimal (B) LRU
(C) FIFO (D) None of these

[GATE 1992 : IIT Delhi]

- Q.26** The optimal page replacement algorithm will select the page that.

 - (A) Has not been used for the longest time in the past
 - (B) Will not be used for the longest time in the future
 - (C) Has been used least number of times
 - (D) Has been used most number of times

[GATE 2002 : IISc Bangalore]

- Q.27** In which one of the following page replacement policies, Belady's anomaly may occur?

- (A) FIFO (B) Optimal
(C) LRU (D) MRU

[GATE 2009 : IIT Roorkee]

- Q.28** Recall that Belady's anomaly is that the

Suppose that the memory can store only one page and if x is the address which causes a page fault then the bytes from addresses x to $x + 99$ are loaded on to the memory. How many page faults will occur ?

[GATE 2007 : IIT Kanpur]

Q.24 Assume that a main memory with only 4 pages, each of 16 bytes, is initially empty. The CPU generates the following sequence of virtual addresses and uses the Least Recently Used (LRU) page replacement policy.

0, 4, 8, 20, 24, 36, 44, 12, 68, 72, 80, 84,
28, 32, 88, 92

How many page faults does this sequence cause? What are the page numbers of the pages present in the

each a_i is a distinct virtual page number. The difference in the number of page faults between the last-in-first-out page replacement policy and the optimal page replacement policy is

[GATE 2016 : IISc Bangalore]

Q.30 A processor uses 2- level page table for virtual to physical address translation. Page tables for both levels are stored in the main memory. Virtual and physical address are both 32 bits wide. The memory is byte addressable. For virtual to physical address translation, the 10 most significant bits for the virtual address are used as index into the first level page table while the next 10 bits are used as index into the second level page table. The 12 least significant bits of the virtual address are used as offset within the page. Assume that the page table entries in both levels of page tables are 4 bytes wide. Further, the processor has a translation look- aside a buffer (TLB), with a hit a rate of 96%. The TLB caches recently used virtual page number and the corresponding physical page numbers. The processor also has a physically address cache with a hit rate of 90%. Main memory access time is 10 ns, cache access time 1 ns, and TLB

page-fault rate may increase as the number of allocated frames increases. Now, consider the following statements:

S1: Random page replacement algorithm (where a page chosen at random is replaced)

Suffers from Belady's anomaly

S2: LRU page replacement algorithm suffers from Belady's anomaly
Which of the following is CORRECT?

- (A) S1 is true, S2 is true
 - (B) S1 is true, S2 is false
 - (C) S1 is false, S2 is true
 - (D) S1 is false, S2 is false

[GATE 2017 : IIT Roorkee]

Q.29 Consider a computer system with ten physical page frames. The system is provided with an access sequence ($a_1, a_2, \dots, a_{20}, a_1, a_2, \dots, a_{20}$), where



first- level table (T_1), which occupies exactly one page. Each entry of T_1 stores the base address of a page of the second- level table (T_2). Each entry of T_2 stores the base address of a page of the third-level table (T_3). Each entry of T_3 stores a page table entry (PTE). The PTE is 32 bits in size. The processor used in the computer has a 1 MB 16-way set associative virtually indexed physically tagged cache. The cache block size is 64 bytes.

What is the size of a page in KB in this computer?

[GATE 2013 : IIT Bombay]

Q.32 In the context of operating systems, which of the following statements is/are correct with respect to paging?

- (A) Page size has no impact on internal fragmentation.
 - (B) Paging incurs memory overheads.
 - (C) Multi-level paging is necessary to support pages of different sizes.
 - (D) Paging helps solve the issue of external fragmentation.

[GATE 2021 : IIT Bombay]

access time also 10 ns.

Suppose a process has only the following pages in its virtual address space: two contiguous code pages starting at virtual address 0x00000000, two contiguous data pages starting at virtual address 0x00400000, and a stack page starting at virtual address 0xFFFFF000. The amount of memory required for storing the page tables of this process is

- (A) 8 KB (B) 12 KB
(C) 16 KB (D) 20 KB

[GATE 2003 : IIT Madras]

- Q.31** A computer uses 64-bit virtual address, 32-bit physical address, and a three-level paged page table organization. The page table base register stores the base address of the

(KB) and the number of segments are given below.

Process	Total size (in KB)	Number of segments
P1	195	4
P2	254	5
P3	45	3
P4	364	8

The page size is 1 KB. The size of an entry in the page table is 4 bytes. The size of an entry in the segment table is 8 bytes. The maximum size of a segment is 256 KB. The paging method for memory management uses two-level paging, and its storage overhead is P. The storage overhead for the segmentation method is S. The storage overhead for the segmentation and paging method is T. What is the relation among the overheads for the different methods of memory management in the concurrent execution of the above four processes ?

- (A) $P < S < T$ (B) $S < P < T$
(C) $S < T < P$ (D) $T < S < P$

[GATE 2006 : IIT Kharagpur]

- Q.35** Which of the following statements is false?

- (A) Virtual memory implements the translation of a program's address space into physical memory address space.
(B) Virtual memory allows each

- Q.33** Consider a 3 level page table to translate a 39 bits virtual address to a physical address As shown below:

Level 1 offset	Level 2 offset	Level 3 offset	Page offset
9bit	9bit	9 bit	12 bit

The page size is 4KB ($1\text{ KB} = 2^{10}\text{ bytes}$) and page table entry size at every level is 8 bytes. A

Process P is currently using 2GB ($1\text{ GB} = 2^{30}\text{ bytes}$) virtual memory which is mapped to 2GB

Of physical memory. The minimum amount of memory required for the page table of P across

All level is _____ KB.

[GATE 2021 : IIT Bombay]

- Q.34** For each of the four processes P1, P2, P3 and P4. The total size in kilobytes

- (D) Programs larger than the physical memory size can be run.

[GATE 1999 : IIT Bombay]

- Q.37** The minimum number of page frames that must be allocated to a running process in a virtual memory environment is determined by.

- (A) The instruction set architecture
(B) Page size
(C) Physical memory size
(D) Number of processes in memory

[GATE 2004 : IIT Delhi]

- Q.38** A Computer system supports 32-bit virtual addresses as well as 32-bit physical addresses. Since the virtual address space is of the same size as the physical address space, the operating system designers decide to get rid of the virtual memory entirely. Which one of the following is true?

- (A) Efficient implementation of multi-user support is no longer possible
(B) The processor cache organization can be made more efficient now
(C) Hardware support for memory management is no longer needed
(D) CPU scheduling can be made more efficient now

[GATE 2006 : IIT Kharagpur]

- Q.39** Locality of reference implies that the page reference being made by a process

program to exceed the size of the primary memory.

(C) Virtual memory increases the degree of multiprogramming.

(D) Virtual memory reduces the context switching overhead.

[GATE 2001 : IIT Kangpur]

- Q.36** Which of the following is/are advantages of virtual memory?

 - (A) Faster access to memory on an average.
 - (B) Processes can be given protected address spaces.
 - (C) Linker can assign addresses independent of where the program will be loaded in physical memory.

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What will be the size of the partition (in physical memory) required to load (and run) this program?

- (A) 12 KB (B) 14 KB
(C) 10KB (D) 8KB

[GATE 1998 : IIT Delhi]

- Q.41** The capacity of memory units is defined by the number of words multiplied by the number of bits/work. How many separate address and data lines are needed for a memory of $4K \times 16$?

- (A) 10 address, 16 data lines
- (B) 11 address, 8 data lines
- (C) 12 address, 16 data lines
- (D) 13 address, 12 data lines

[GATE 1995 : IIT Kanpur]

- Q.42** A computer installation has 1000k of main memory. The jobs arrive and finish in the following sequences.

Job 1 requiring 200k arrives
Job 2 requiring 350k arrives
Job 3 requiring 300k arrives
Job 1 finishes

Job 4 requiring 120k arrives
Job 5 requiring 150k arrives
Job 6 requiring 80k arrives

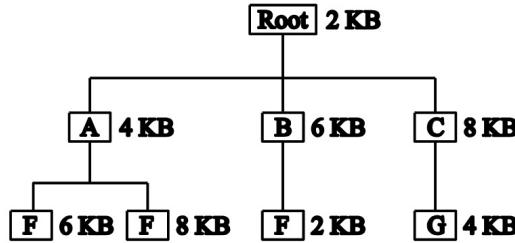
(a) Draw the memory allocation table using Best Fit and First fit algorithms.

(b) Which algorithm performs better for this sequence?

[GATE 1995 : IIT Kharagpur]

- (A) Will always be to the page used in the previous page reference
 - (B) Is likely to be one of the pages used in the last few page references
 - (C) Will always be to one of the pages existing in memory
 - (D) Will always lead to page fault

Q.40 The overlay tree for a program is as shown below:



virtual memory. The memory is byte addressable. Both virtual and physical address spaces contain 2¹⁶ bytes each. The virtual address space is divided into 8 non-overlapping equal size segments. The memory management unit (MMU) has a hardware segment table, each entry of which contains the physical address of the page table for the segment. Page tables are stored in the main memory and consists of 2¹² byte page table entries.

- (a) What is the minimum page size in bytes so that the page table for a segment requires at most one page to store it? Assume that the page size can only be a power of 2.

(b) Now suppose that the pages size is 512 bytes. It is proposed to provide a TLB (Transaction look-aside buffer) for speeding up address translation. The proposed TLB will be capable of storing page table entries for 16 recently referenced virtual pages, in a fast cache that will use the direct mapping scheme. What is the number of tag bits that will need to be associated with each cache entry?

(c) Assume that each page table entry contains (besides other information) 1 valid bit, 3 bits for page protection and 1 dirty bit. How many bits are available in page table entry for storing the aging

- (A) Virtual page number.
- (B) Page frame number.
- (C) Both virtual page number and page frame number
- (D) Access right information.

[GATE 2009 : IIT Roorkee]

- Q.2** In paged memory systems, if the page size is increased, then the internal fragmentation generally:
- (A) Becomes less
 - (B) Becomes more
 - (C) Remains constant
 - (D) None of the mentioned

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the maximum size of the page table of a process is 24 megabytes, the length of the virtual address supported by the system is _____ bits.

[GATE 2015 : IIT Kanpur]

- Q.5** Dirty bit for a page in a page table
- (A) Helps avoid unnecessary writes on paging device
 - (B) Helps maintain LUR information
 - (C) Allow only read on a page
 - (D) None of the above

[GATE 1997 : IIT Madras]

- Q.6** Suppose the time to service a page fault is on the average 10 milliseconds, while a memory access takes 1 microsecond. Then a 99.99% hit ratio results in average memory access time of
- (A) 1.9999 milliseconds
 - (B) 1 millisecond
 - (C) 9.999 microseconds
 - (D) 1.9999 microseconds

[GATE 2000 : IIT Kharagpur]

- Q.7** A paging scheme uses a Translation Look-aside Buffer (TLB). A TLB-access takes 10 ns and a main memory access takes 50 ns. What is the effective access time (in ns) if the TLB hit ratio is 90% and there is no page-fault?
- | | |
|--------|--------|
| (A) 54 | (B) 60 |
| (C) 65 | (D) 75 |

[GATE 2008 : IISc Bangalore]

- Q.8** Thrashing
- (A) Reduces page I/O

memory is to increase the effective speed of the memory system.

- (B) The main objective for using virtual memory is to increase the effective capacity of the memory system.
- (C) The size of main memory is larger as compared to cache memory.
- (D) Main memory is faster as compared to cache memory.

- Q.4** A computer system implements 8 kilobyte pages and a 32-bit physical address space. Each page table entry contains a valid bit, a dirty bit, three permission bits, and the translation. If

- 
- (B) Always increase the number of page faults
 - (C) Sometimes increase the number of page faults
 - (D) Never affect the number of page faults.

- Q.10** In which one of the following page replacement algorithms it is possible for the page fault rate to increase even when the number of allocated frames increases?
- (A) LRU (Least Recently Used)
 - (B) OPT (Optimal Page Replacement)
 - (C) MRU (Most Recently Used)
 - (D) FIFO (First In First Out)

[GATE 2016 : IISc Bangalore]

Common Data for Questions 11 & 12

- Q.11** A process has been allocated 3 page frames. Assume that none of the pages of the process are available in the memory initially. The process makes the following sequence of page references (reference string): 1, 2, 1, 3, 7, 4, 5, 6, 3, 1

If optimal page replacement policy is used, how many page faults occur for the above reference string?

- | | |
|-------|--------|
| (A) 7 | (B) 8 |
| (C) 9 | (D) 10 |

[GATE 2007 : IIT Kanpur]

- Q.12** Least Recently Used (LRU) page replacement policy is a practical approximation to optimal page

- (B) Decreases the degree of multiprogramming
- (C) Implies excessive page I/O
- (D) Improves the system performance

[GATE 1997 : IIT Madras]

- Q.9** Consider a virtual memory system with FIFO page replacement policy. For an arbitrary page access pattern, increasing the number of page frames in main memory will
- (A) Always decrease the number of page faults

- (B) It helps to reduce the size of page table needed to implement the virtual address space of a process.
- (C) It is required by the translation lookaside buffer.
- (D) It helps to reduce the number of page faults in page replacement algorithms.

[GATE 2009 : IIT Roorkee]

- Q.14** How many address and data lines will be there for a $16\text{ M} \times 32$ memory system?
- (A) 24 and 5
 - (B) 20 and 32
 - (C) 24 and 32
 - (D) None of the above
- Q.15** The principle of locality justifies the use of
- (A) Interrupts
 - (B) DMA
 - (C) Polling
 - (D) Cache Memory

[GATE 1995 : IIT Kanpur]

- Q.16** What is the swap space in the disk used for?
- (A) Saving temporary html pages
 - (B) Saving process data
 - (C) Storing the super-block
 - (D) Storing device drivers

[GATE 2005 : IIT Bombay]

replacement. For the above reference string, how many more page faults occur with LRU than with the optimal page replacement policy?

- (A) 0
- (B) 1
- (C) 2
- (D) 3

[GATE 2007 : IIT Kanpur]

- Q.13** A multilevel page table is preferred in comparison to a single level page table for translating virtual address to physical address because
- (A) It reduces the memory access time to read or write a memory location.

- Q.17** A computer system uses 32-bit virtual address, and 32-bit physical address. The physical memory is byte addressable, and the page size is 4 kbytes. It is decided to use two level page tables to translate from virtual address to physical address. Equal number of bits should be used for indexing first level and second level page table, and the size of each page table entry is 4 bytes.

- (A) What is the number of page table entries that can be contained in each page?
- (B) How many bits are available for storing protection and other information in each page table entry?

[GATE 2002 : IISc Bangalore]

- Q.18** For implementing demand paging, it is required to –
- (A) Distinguish between the pages that are in memory and the pages that are on disk
 - (B) Use a variation of valid-invalid scheme for protection
 - (C) Implement new MMU functionality
 - (D) All of the above

[GATE 2002 : IISc Bangalore]

5**First System and Device Management** **Classroom Questions**

- Q.1** The root directory of a disk should be placed:
- At a fixed address in main memory
 - At a fixed location on the disk
 - Any where on the disk
 - At a fixed location on the system disk

[GATE 1993 : IIT Bombay]

- Q.2** The data blocks of a very large file in the Unix file system are allocated using
- Contiguous allocation
 - Linked allocation
 - Indexed allocation
 - An extension of indexed allocation.

[GATE 2008 : IISc Bangalore]

- Q.3** The index node (inode) of a Unix-like file system has 12 direct, one single-indirect and one double-indirect pointer. The disk block size is 4 kB and the disk block addresses 32-bits long. The maximum possible file size is (rounded off to 1 decimal place) _____ GB.

[GATE 2019 : IIT Madras]

- Q.5** In a particular Unix OS, each data block is of size 1024 bytes, each node has 10 direct data block addresses and three additional addresses: one for single indirect block, one for double indirect

- Q.6** In a computer system, four files of size 11050 bytes, 4990 bytes, 5170 bytes and 12640 bytes need to be stored. For storing these files on disk, we can use either 100 byte disk blocks or 200 byte disk blocks (but can't mix block sizes). For each block used to store a file, 4 bytes of bookkeeping information also needs to be stored on the disk. Thus, the total space used to store a file is the sum of the space taken to store the file and the space taken to store the book keeping information for the blocks allocated for storing the file. A disk block can store either bookkeeping information for a file or data from a file, but not both. What is the total space required for storing the files using 100 byte disk blocks and 200 byte disk blocks respectively?
- 35400 and 35800 bytes
 - 35800 and 35400 bytes
 - 35600 and 35400 bytes
 - 35400 and 35600 bytes

[GATE 2005 : IIT Bombay]

- If the overhead for formatting a disk is 96 bytes for a 4000 byte sector,
- Compute the unformatted capacity of the disk for the following parameters:
Number of surfaces: 8
Outer diameter of the disk: 12 cm
Inner diameter of the disk: 1 cm

block and one for triple indirect block. Also, each block can contain addresses for 128 blocks. Which one of the following is approximately the maximum size of a file in the file system?

- (A) 512 MB (B) 2GB
(C) 8GB (D) 16GB

[GATE 2004 : IIT Delhi]



Q.7 A hard disk has 63 sectors per track, 10 platters each with 2 recording surfaces and 1000 cylinders. The address of a sector is given as a triple $\langle c, h, s \rangle$, where c is the cylinder number, h is the surface number and s is the sector number. Thus, the 0th sector is addressed as $\langle 0, 0, 0 \rangle$, the 1st sector as $\langle 0, 0, 1 \rangle$, and so on

The address of the 1039th sector is

- (A) $\langle 0, 15, 31 \rangle$ (B) $\langle 0, 16, 30 \rangle$
(C) $\langle 0, 16, 31 \rangle$ (D) $\langle 0, 17, 31 \rangle$

[GATE 2009 : IIT Roorkee]

Q.8 A hard disk has 63 sectors per track, 10 platters each with 2 recording surfaces and 1000 cylinders. The address of a sector is given as a triple $\langle c, h, s \rangle$, where c is the cylinder number, h is the surface number and s is the sector number. Thus, the 0th sector is addressed as $\langle 0, 0, 0 \rangle$, the 1st sector as $\langle 0, 0, 1 \rangle$, and so on

The address $\langle 400, 16, 29 \rangle$ corresponds to sector number:

- (A) 505035 (B) 505036
(C) 505037 (D) 505038

[GATE 2009 : IIT Roorkee]

Q.9 An application loads 100 libraries at startup. Loading each library requires exactly one disk access. The seek time of the disk to a random location is given as 10 ms. Rotational speed of disk is 6000 rpm. If all 100 libraries are loaded from random locations on the disk, how long does it take to load all libraries? (The time to transfer data from the disk block once the head has been positioned at the start of the block may be neglected.)

- (A) 0.50 s (B) 1.50 s
(C) 1.25 s (D) 1.00 s

inner diameter of the disk: 4 cm

Inner track space: 0.1 mm

Number of sectors per track: 20

(b) If the disk in (a) is rotating at 360 rpm, determine the effective data transfer rate which is defined as the number of bytes transferred per second between disk and memory.

[GATE 2011 : IIT Madras]

The average latency of this device is P msec and the data transfer rate is Q bits/sec.

Write the value of P and Q

[GATE 1993 : IIT Bombay]

Q.11 A file system with a one-level directory structure is implemented on a disk with disk block size of 4 K bytes. The disk is used as follows:

Disk-block 0: File Allocation Table, consisting of one 8-bit entry per data block, representing the data block address of the next data block in the file

Disk block 1: Directory, with one 32 bit entry per file:

Disk block 2: Data block 1;
Disk block 3: Data block 2; etc.

- (A) What is the maximum possible number of files?
(B) What is the maximum possible file size in blocks?

[GATE 1996 : IISc Bangalore]

Q.12 Consider a disk pack with 16 surfaces, 128 tracks per surface and 256 sectors per track. 512 bytes of data are stored in a bit serial manner in a sector. The capacity of the disk pack and the number of bits required to specify a particular sector in the disk are respectively:

- (A) 256 Mbyte, 19 bits
(B) 256 Mbyte, 28 bits
(C) 512 Mbyte, 20 bits
(D) 64 Gbyte, 28 bits

[GATE 2007 : IIT Kanpur]

Q.13 A disk has 200 tracks (numbered 0 through 199). At a given time, it was servicing the request of reading data from track 120, and at the previous request, service was for track 90. The pending requests (in order of their arrival) are for track numbers

Q.10 A certain moving arm disk storage, with one head, has the following specifications.

Number of tracks/recording surface =
200
Disk rotation speed = 2400 rpm
Track storage capacity = 62,500 bits

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Q.14 Disk requests come to disk driver for cylinders 10, 22, 20, 2, 40, 06 and 38, in that order at a time when the disk drive is reading from cylinder 20. The seek time is 6 msec per cylinder. Computer the total seek time if the disk arm scheduling algorithm is

- (A) First come first served
 - (B) Closest cylinder next

[GATE 2014 : IIT Kharagpur]

Q.15 Consider a disk queue with requests for I/O to blocks on cylinders 47, 38, 121, 191, 87, 11, 92, 10. The C-LOOK scheduling algorithm is used. The head is initially at cylinder number 63, moving towards larger cylinder numbers on its servicing pass. The cylinders are numbered from 0 to 199. The total head movement (in number of cylinders) incurred while servicing these requests is _____.

[GATE 2016 : IISc Bangalore]

Q.16 Suppose the following disk request sequence (track number) for a disk with 100 tracks is given: 45, 20, 90, 10, 50, 60, 80, 25, 70. Assume that the initial position of the R/W head is on track 50. The additional distance that will be traversed by the R/W head when the Shortest Seek Time First (SSTF) algorithm is used compared to the SCAN (Elevator) algorithm (assuming that SCAN algorithm moves towards 100 when it starts execution) is _____ tracks.

[GATE 2015 : IIT Kanpur]

Q.17 Consider a disk system with 100 cylinders. The requests to access the cylinders occur in following sequence:

Assuming that the head is currently at cylinder 50, what is the time taken to

until arrival at the black mounds.

30 70 115 130 110 80 20 25.

How many times will the head change its direction for the disk scheduling policies SSTF(Shortest Seek Time First) and FCFS (First Come Fist Serve)

[GATE 2004 : IIT Delhi]



Q.18 Consider a storage disk with 4 platters (numbered as 0, 1, 2 and 3), 200 cylinders (numbered as 0, 1, ..., 199), and 256 sectors per track (numbered as 0, 1, ... 255). The following 6 disk requests of the form [sector number, cylinder number, platter number] are received by the disk controller at the same time:

[120, 72, 2], [180, 134, 1], [60, 20, 0], [212, 86, 3], [56, 116, 2], [118, 16, 1]

Currently head is positioned at sector number 100 of cylinder 80, and is moving towards higher cylinder numbers. The average power dissipation in moving the head over 100 cylinders is 20 milliwatts and for reversing the direction of the head movement once is 15 milliwatts. Power dissipation associated with rotational latency and switching of head between different platters is negligible.

The total power consumption in milliwatts to satisfy all of the above disk requests using the Shortest Seek Time First disk scheduling algorithm is

[GATE 2018 : IIT Guwahati]

Q.19 Consider a disk with the 100 tracks numbered from 0 to 99 rotating at 3000 rpm. The number of sectors per track is 100. the time to move the head between two successive tracks is 0.2 millisecond.

Consider a set of disk requests to read data from tracks 32, 7, 45, 5 and 10. Assuming that the elevator algorithm is used to schedule disk requests, and the head is initially at track 25 moving up (towards larger track numbers), what is the total seek time for servicing the requests?

[GATE 2001 : IIT Kanpur]

Q.20 The head of a hard disk serves requests following the shortest seek time first

satisfy all requests if it takes 1 ms to move from one cylinder to adjacent one and shortest seek time first policy is used?

- (A) 95 ms (B) 119 ms
(C) 233 ms (D) 276 ms

[GATE 2009 : IIT Roorkee]

requests arrive before the servicing starts?

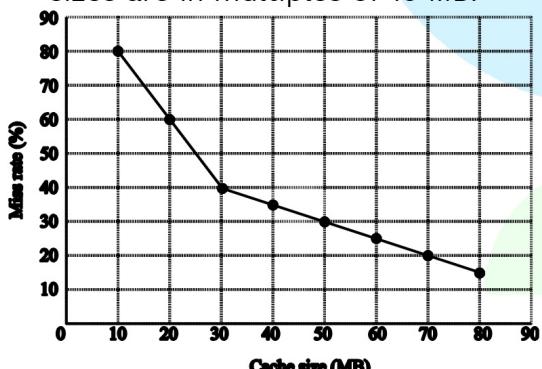
- (A) 11, 139, 170, 178, 181, 184, 201, 265
(B) 10, 138, 170, 178, 181, 185, 201, 265
(C) 10, 139, 169, 178, 181, 184, 201, 265
(D) 10, 138, 170, 178, 181, 185, 200, 265

[GATE 2007 : IIT Kanpur]

Q.21 What is the maximum cardinality of the request set, so that the head changes its direction after servicing every request if the total number of tracks are 2048 and the head can start from any track?

[GATE 2007 : IIT Kanpur]

Q.22 A file system uses an in- memory cache to cache disk blocks. The miss rate of the cache is shown in the figure. The latency to read a block from the cache is 1 ms and to read a block from the disk is 10 ms. Assume that the cost of checking whether a block exists in the cache is negligible. Available cache sizes are in multiples of 10 MB.



The smallest cache size required to ensure an average read latency of less than 6 ms is _____ MB.

[GATE 2016 : IISc Bangalore]

Q.23 Consider an operating system capable of loading and executing a single sequential user process at a time. The disk head scheduling algorithm used is First Come First Served (FCFS). If FCFS is replaced by Shortest Seek Time First (SSTF), claimed by the vendor to give

(SSTF) policy. The head is initially positioned at track number 180.

Which of the request sets will cause the head to change its direction after servicing every request assuming that the head does not change direction if there is a tie in SSTF and all the

Q.24 Which of the following disk scheduling strategies is likely to give the best throughput?

- (A) Farthest cylinder next
 - (B) Nearest cylinder next
 - (C) First come first served
 - (D) Elevator algorithm

[GATE 1999 : IIT Bombay]

Q.25 Using a larger block size in a fixed block size file system leads to

- (A) Better disk throughput but poorer disk space utilization
 - (B) Better disk throughput and better disk space utilization
 - (C) Poorer disk throughput but better disk space utilization
 - (D) Poorer disk throughput and poorer disk space utilization

[GATE 2003 : IIT Madras]

Q.26 When an interrupt occurs, an Operating System

- (A) Ignores the interrupt
 - (B) Always changes state of interrupted process to ‘blocked’ and schedules another process.
 - (C) Always resumes execution of interrupted process after processing the interrupts.
 - (D) May change state of interrupted processor to “blocked and schedule another process.

[GATE 1997 : IIT Madras]

Q.27 Which of the following devices should get higher priority in assigning interrupts?

- (A) Hard disk (B) Printer
(C) Keyboard (D) Floppy disk

[GATE 1998 : IIT Delhi]

Q.28 Listed below are some operating system abstraction (in the left column) and the hardware components (Right column). Which matching pair is correct?

50% better benchmark results, what is the expected improvement in the I/O performance of user programs?

- (A) 50% (B) 40%
(C) 25% (D) 0%

[GATE 2004 : IIT Delhi]

- (a) Thread (1. Interrupt
(b) Virtual Address (2. Memory
space
(c) File System (3. CPU
(d) Signal (4. Disk

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- (A) A-2, B-4, C-3, D-1
(B) A-1, B-2, C-3, D-4
(C) A-3, B-2, C-4, D-1
(D) A-4, B-1, C-2, D-3

[GATE 1999 : IIT Bombay]

Q.29 Which of the following requires a device driver?

- (A) Register (B) Cache
(C) Main memory (D) Disk

[GATE 2001 : IIT Kanpur]

- Q.30** A file system with 300 GB disk uses a file descriptor with 8 direct block addresses, 1 indirect block address and 1 doubly indirect block address. The size of each disk block is 128 Bytes and the size of each disk block address is 8 Bytes. The maximum possible file size in this file system is
(A) 3 KB
(B) 35 KB
(C) 280 KB
(D) Dependent on the size of the disk

[GATE 2012 : IIT Delhi]

Practice Questions

Q.1 In a file allocation system, which of the following allocation scheme(s) can be used if no external fragmentation is allowed?

- I. Contiguous
II. Linked
III. Indexed
(A) I and III only (B) II only
(C) III only (D) II and III only

Q.2 In the index allocation scheme of blocks to a file, the maximum possible size of the file depends on

- (A) The size of the blocks, and the size of the address of the blocks.
(B) The number of blocks used for the index, and the size of the blocks.
(C) The size of the blocks, the number of blocks used for the index, and the size of the address of the blocks.
(D) None of the above.

Q.3 The correct matching for the following

- | List- I | List- II |
|--------------------------|-----------------|
| (a) Disk scheduling | (1) Round robin |
| (b) Batch processing | (2) SCAN |
| (c) Time sharing | (3) LIFO |
| (d) Interrupt processing | (4) FIFO |

Q.4 Consider a hard disk with 16 recording surfaces (0-15) having 16384 cylinders (0-16383) and each cylinder contains 64 sectors (0-63). Data storage capacity in each sector is 512 bytes. Data are organized cylinder-wise and the addressing format is. A file of size 42797 KB is stored in the disk and the starting disk location of the file is <1200, 9, 40>. What is the cylinder number of the last sector of the file, if it is stored in a contiguous manner?

- (A) 1281 (B) 1282
(C) 1283 (D) 1284

Q.5 A certain moving arm disc-storage has the following a specification:

Number of track per surface=4004
Track the storage capacity=130030 bytes

Disk speed =3600 rpm

Average seek time=30 m secs.

Estimate the average latency the disc storage capacity and that data transfer rate.

Q.6 Suppose a disk has 201 cylinders, numbered from 0 to 200. At some time the disk arm is at cylinder 100, and there is a queue of disk access requests for cylinders 30, 85, 90, 100, 105, 110, 135 and 145. If Shortest- Seek Time First (SSTF) is being used for

- (A) a-3, b-4, c-2, d-1
 - (B) a-4, b-3, c-2, d-1
 - (C) a-2, b-4, c-1, d-3
 - (D) a-3, b-4, c-3, d-2

scheduling the disk access, the request for cylinder 90 is serviced after servicing _____ number of requests.



- Q.7** Which of the following secondary storage technology does not support random access?

 - (A) Tape
 - (B) Magnetic Disk
 - (C) Flash Disk
 - (D) None of the above

Q.8 Which of the following is/are represented by an i-node ?

 - (A) Files
 - (B) Directories
 - (C) Pipes
 - (D) None

- Q.9** Which of the following are true for disk fragmentation?

 - (A) On increasing block size the maximum size of the file that can be stored increases.
 - (B) Contiguous allocation strategy suffers from external fragmentation.
 - (C) Linked list allocation strategy suffers from external fragmentation.
 - (D) On increasing block size internal fragmentation increases.



