Q. No. 1 – 20 Carry One Mark Each

1. Which one of the following in NOT necessarily a property of a Group?
   (A) Commutativity (B) Associativity
   (C) Existence of inverse for every element (D) Existence of identity

2. What is the chromatic number of an n-vertex simple connected graph which does not contain any odd length cycle? Assume $n \geq 2$.
   (A) 2 (B) 3 (C) n-1 (D) n

3. Which one of the following is TRUE for any simple connected undirected graph with more than 2 vertices?
   (A) No two vertices have the same degree.
   (B) At least two vertices have the same degree.
   (C) At least three vertices have the same degree.
   (D) All vertices have the same degree.

4. Consider the binary relation R = {(x,y), (x,z), (z,x), (z,y)} on the set {x,y,z}. Which one of the following is TRUE?
   (A) R is symmetric but NOT antisymmetric
   (B) R is NOT symmetric but antisymmetric
   (C) R is both symmetric and antisymmetric
   (D) R is neither symmetric nor antisymmetric

5. $(1217)_8$ is equivalent to
   (A) $(1217)_{16}$ (B) $(028F)_{16}$ (C) $(2297)_{10}$ (D) $(0B17)_{16}$

6. What is the minimum number of gates required to implement the Boolean function (AB+C) if we have to use only 2-input NOR gates?
   (A) 2 (B) 3 (C) 4 (D) 5

7. How many 32K x 1 RAM chips are needed to provide a memory capacity of 256K-bytes?
   (A) 8 (B) 32 (C) 64 (D) 128

8. A CPU generally handles an interrupt by executing an interrupt service routine
   (A) As soon as an interrupt is raised
   (B) By checking the interrupt register at the end of fetch cycle.
   (C) By checking the interrupt register after finishing the execution of the current instruction.
   (D) By checking the interrupt register at fixed time intervals.

9. In which one of the following page replacement policies, Belady's anomaly may occur?
(A) FIFO (B) Optimal (C) LRU (D) MRU

10. The essential content(s) in each entry of a page table is / are
(A) Virtual page number
(B) Page frame number
(C) Both virtual page number and page frame number
(D) Access right information

11. What is the number of swaps required to sort n elements using selection sort, in the worst case?
(A) $\theta(n)$ (B) $\theta(n \log n)$ (C) $\theta(n^2)$ (D) $\theta(n^2 \log n)$

12. $S \rightarrow aSa|bSb|a|b$;The language generated by the above grammar over the alphabet {a,b} is the set of
(A) All palindromes.
(B) All odd length palindromes.
(C) Strings that begin and end with the same symbol
(D) All even length palindromes.

13. Which of the following statement(s) is / are correct regarding Bellman-Ford shortest path algorithm?
P. Always finds a negative weighted cycle, if one exists.
Q. Finds whether any negative weighted cycle is reachable from the source.
(A) P only (B) Q only
(C) both P and Q (D) Neither P nor Q

14. Let π_A be a problem that belongs to the class NP. Then which one of the following is TRUE?
(A) There is no polynomial time algorithm for π_A.
(B) If π_A can be solved deterministically in polynomial time, then P = NP.
(C) If π_A is NP-hard, then it is NP-complete.
(D) π_A may be undecidable.

15. Which one of the following languages over the alphabet {0,1} is described by the regular expression: (0+1)*0(0+1)*0(0+1)*?
(A) The set of all strings containing the substring 00.
(B) The set of all strings containing at most two 0's.
(C) The set of all strings containing at least two 0's.
(D) The set of all strings that begin and end with either 0 or 1.

16. Which one of the following is FALSE?

(A) There is unique minimal DFA for every regular language

(B) Every NFA can be converted to an equivalent PDA.

(C) Complement of every context-free language is recursive.

(D) Every nondeterministic PDA can be converted to an equivalent deterministic PDA.

17. Match all items in Group 1 with correct options from those given in Group 2.

Group 1		Group 2	
P.	Regular expression	1.	Syntax analysis
Q.	Pushdown automata	2.	Code generation
R.	Dataflow analysis	3.	Lexical analysis
S.	Register allocation	4.	Code optimization

(A) P-4. Q-1, R-2, S-3 (B) P-3, Q-1, R-4, S-2

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

18. Consider the program below:

```
# include < stdio.h >
int fun(int n, int * f_p) {
        int t, f;
        if (n <= 1) {
                *f_p = 1;
                return 1;
        }
        t = fun (n- 1, f_p);
        f = t+ *f_p;
        *f_p = t;
        return f;
}
int main() {
        int x = 15;
        printf ("%d\n", fun(5,& x));
        return 0;
}
```

The value printed is

(A) 6 (B) 8 (C) 14 (D) 15

19. The coupling between different modules of a software is categorized as follows:

I. Content coupling II. Common coupling

III. Control coupling IV Stamp coupling

V. Data coupling

Coupling between modules can be ranked in the order of strongest (least desirable) to weakest (most desirable) as follows:

(A) I-II-III-IV-V (B) V-IV-III-II-I (C) I-III-V -II-IV (D) IV-II-V -III-I

20. Consider the HTML table definition given below:

```
< table border=1>
        <tr> <td rowspan=2> ab </td>
            <td colspan=2> cd </td>
        </tr>
        <tr> <td> ef </td>
            <td rowspan=2> gh </td>
        </tr>
        <tr> <td colspan=2> ik </td>
        </tr>
</table>
```

The number of rows in each column and the number of columns in each row are:

(A) $\langle 2,2,3 \rangle$ and $\langle 2,3,2 \rangle$ (B) $\langle 2,2,3 \rangle$ and $\langle 2,2,3 \rangle$

(C) $\langle 2,3,2 \rangle$ and $\langle 2,3,2 \rangle$ (D) $\langle 2,3,2 \rangle$ and $\langle 2,2,3 \rangle$

Q. No. 21 – 56 Carry Two Marks Each

21. An unbalanced dice (with 6 faces, numbered from 1 to 6) is thrown. The probability that the face value is odd is 90% of the probability that the face value is even. The probability of getting any even numbered face is the same.

If the probability that the face is even given that it is greater than 3 is 0.75, which one of the following options is closest to the probability that the face value exceeds 3?

(A) 0.453 (B) 0.468 (C) 0.485 (D) 0.492

22. For the composition table of a cyclic group shown below

*	a	b	c	d
a	a	b	c	d
b	b	a	d	c
c	c	d	b	a
d	d	c	a	b

Which one of the following choices is correct?

(A) a, b are generators (B) b, c are generators

(C) c, d are generators (D) d, a are generators

23. Which one of the following is the most appropriate logical formula to represent the statement? "Gold and silver ornaments are precious".

The following notations are used:

G(x): x is a gold ornament

S(x): x is a silver ornament

P(x): x is precious

(A) $\forall x\left(P(x) \rightarrow \left(G(x) \wedge S(x)\right)\right)$ (B) $\forall x\left(\left(G(x) \wedge S(x)\right) \rightarrow P(x)\right)$

(C) $\exists x\left(\left(G(x) \wedge S(x)\right) \rightarrow P(x)\right)$ (D) $\forall x\left(\left(G(x) \vee S(x)\right) \rightarrow P(x)\right)$

24. The binary operation □ is defined as follows

P	Q	P□Q
T	**T**	**T**
T	**F**	**T**
F	**T**	**F**
F	**F**	**T**

Which one of the following is equivalent to $P \vee Q$?

(A) $\neg Q \square \neg P$ (B) $P \square \neg Q$ (C) $\neg P \square Q$ (D) $\neg P \square \neg Q$

25. $\int_0^{\pi/4} (1-\tan x)/(1+\tan x)\,dx$ evaluates to

(A) 0 (B) 1 (C) ln 2 (D) $\frac{1}{2}$ ln 2

26. Consider the following well-formed formulae:

I. $\neg\forall x(P(x))$ II. $\neg\exists x(P(x))$ III. $\neg\exists x(\neg P(x))$ IV. $\neg\exists x(\neg P(x))$

Which of the above are equivalent?

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

27. Given the following state table of an FSM with two states A and B, one input and one output:

Present State A	Present State B	Input	Next State A	Next State B	Output
0	0	0	0	0	1
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	1	0	0
0	0	1	0	1	0
0	1	1	0	0	1
1	0	1	0	1	1
1	1	1	0	0	1

If the initial state is A = 0, B=0, what is the minimum length of an input string which will take the machine to the state A=0, B=1 with Output=1?

(A) 3 (B) 4 (C) 5 (D) 6

28. Consider a 4 stage pipeline processor. The number of cycles needed by the four instructions I1, I2, I3, I4 in stages S1, S2, S3, S4 is shown below:

	S1	S2	S3	S4
I1	2	1	1	1
I2	1	3	2	2
I3	2	1	1	3
I4	1	2	2	2

What is the number of cycles needed to execute the following loop?

For (i=1 to 2) {I1; I2; I3; I4;}

(A) 16 (B) 23 (C) 28 (D) 30

29. Consider a 4-way set associative cache (initially empty) with total 16 cache blocks. The main memory consists of 256 blocks and the request for memory blocks is in the following order:

0, 255, 1, 4, 3, 8, 133, 159, 216, 129, 63, 8, 48, 32, 73, 92, 155.

Which one of the following memory block will NOT be in cache if LRU replacement policy is used?

(A) 3 (B) 8 (C) 129 (D) 216

30. Consider a system with 4 types of resources R1 (3 units), R2 (2 units), R3 (3 units), R4 (2 units). A non-preemptive resource allocation policy is used. At any given instance, a request is not entertained if it cannot be completely satisfied. Three processes P1, P2, P3 request the sources as follows if executed independently.

Process P1:	Process P2:	Process P3:
t=0: requests 2 units of R2	t=0: requests 2 units of R3	t=0: requests 1 unit of R4
t=1: requests 1 unit of R3	t=2: requests 1 unit of R4	t=2: requests 2 units of R1
t=3: requests 2 units of R1	t=4: requests 1 unit of R1	t=5: releases 2 units of R1
t=5: releases 1 unit of R2 and 1 unit of R1.	t=6: releases 1 unit of R3	t=7: requests 1 unit of R2
t=7: releases 1 unit of R3	t=8: Finishes	t=8: requests 1 unit of R3
t=8: requests 2 units of R4		t=9: Finishes
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 a deadlock.

(D) All three processes will be in deadlock.

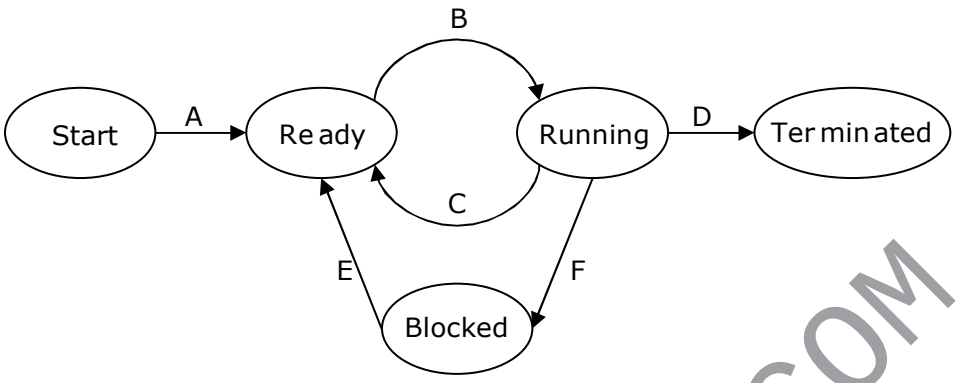
31. Consider a disk system with 100 cylinders. The requests to access the cylinders occur in following sequence:

4, 34, 10, 7, 19, 73, 2, 15, 6, 20

Assuming that the head is currently at cylinder 50, what is the time taken to satisfy all requests if it takes 1ms to move from one cylinder to adjacent one and shortest seek time first policy is used?

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

32. 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 P_2 in blocked state can make transition E while another process P_1 is in running state.

III. The OS uses preemptive scheduling.

IV. The OS uses non-preemptive scheduling.

Which of the above statements are TRUE?

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

33. The enter_CS() and leave_CS() functions to implement critical section of a process are realized using test-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 is TRUE?

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

34. 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.

(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.

35. The running time of an algorithm is represented by the following recurrence relation:

$$T(n) = \begin{cases} n & n \le 3 \\ T\left(\frac{n}{3}\right) + cn & \text{otherwise} \end{cases}$$

Which one of the following represents the time complexity of the algorithm?

(A) $\theta(n)$ (B) $\theta(n \log n)$ (C) $\theta(n^2)$ (D) $\theta(n^2 \log n)$

36. The keys 12, 18, 13, 2, 3, 23, 5 and 15 are inserted into an initially empty hash table of length 10 using open addressing with hash function h(k) = k mod 10 and linear probing. What is the resultant hash table?

(A)

0	
1	
2	2
3	23
4	
5	15
6	
7	
8	18
9	

(B)

0	
1	
2	12
3	13
4	
5	5
6	
7	
8	18
9	

(C)

0	
1	
2	12
3	13
4	2
5	3
6	23
7	5
8	18
9	15

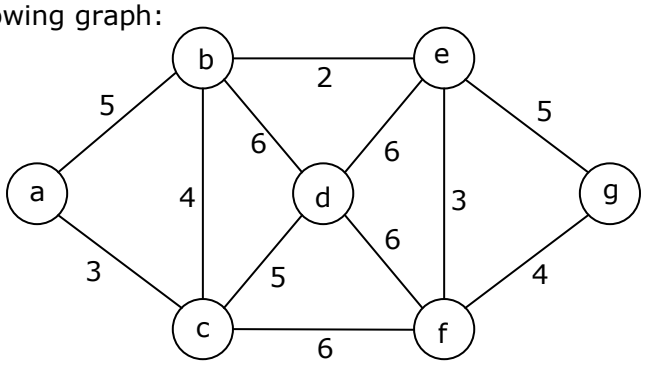
(D)

0	
1	
2	12,2
3	13,3,23
4	
5	5,15
6	
7	
8	18
9	

37. What is the maximum height of any AVL-tree with 7 nodes? Assume that the height of a tree with a single node is 0.

(A) 2 (B) 3 (C) 4 (D) 5

38. Consider the following graph:



Which one of the following is NOT the sequence of edges added to the minimum spanning tree using Kruskal's algorithm?

(A) (b,e) (e,f) (a,c) (b,c) (f,g) (c,d)
(B) (b,e) (e,f) (a,c) (f,g) (b,c) (c,d)
(C) (b,e) (a,c) (e,f) (b,c) (f,g) (c,d)
(D) (b,e) (e,f) (b,c) (a,c) (f,g) (c,d)

39. In quick sort, for sorting n elements, the $(n/4)^{th}$ smallest element is selected as pivot using an O(n) time algorithm. What is the worst case time complexity of the quick sort?

(A) $\theta(n)$ (B) $\theta(n \log n)$ (C) $\theta(n^2)$ (D) $\theta(n^2 \log n)$

40. Let $L = L_1 \cap L_2$, where L_1 and L_2 are languages as defined below:

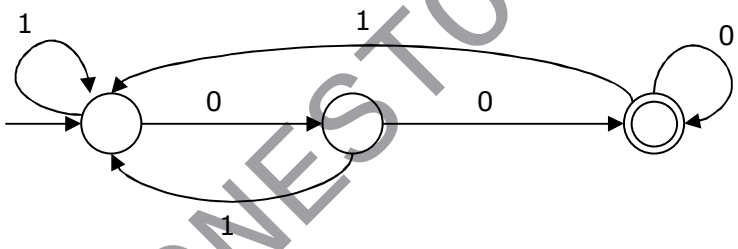
$L_1 = \{a^m b^m c a^n b^m \mid m, n \geq 0\}$

$L_2 = \{a^i b^j c^k \mid i, j, k \geq 0\}$

Then L is

(A) Not recursive
(B) Regular
(C) Context free but not regular
(D) Recursively enumerable but not context free.

41.



The above DFA accepts the set of all strings over {0,1} that

(A) begin either with 0 or 1
(B) end with 0
(C) end with 00
(D) contain the substring 00.

42. Which of the following statements are TRUE?

I There exist parsing algorithms for some programming languages whose complexities are less than $\theta(n^3)$.

II A programming language which allows recursion can be implemented with static storage allocation.

III No L-attributed definition can be evaluated in the framework of bottom-up parsing.

IV Code improving transformations can be performed at both source language and intermediate code level.

(A) I and II (B) I and IV (C) III and IV (D) I, III and IV

43. Consider two transactions T_1 and T_2, and four schedules S_1, S_2, S_3, S_4 of T_1 and T_2 as given below:

$T_1 : R_1[x] W_1[x] W_1[y]$
$T_2 : R_2[x] R_2[y] W_2[y]$
$S_1 : R_1[x] R_2[x] R_2[y] W_1[x] W_1[y] W_2[y]$
$S_2 : R_1[x] R_2[x] R_2[y] W_1[x] W_2[y] W_1[y]$
$S_3 : R_1[x] W_1[x] R_2[x] W_1[y] R_2[y] W_2[y]$
$S_4 : R_2[x] R_2[y] R_1[x] W_1[x] W_1[y] W_2[y]$

Which of the above schedules are conflict-serializable?

(A) S_1 and S_2 (B) S_2 and S_3 (C) S_3 only (D) S_4 only

44. The following key values are inserted into a B+ - tree in which order of the internal nodes is 3, and that of the leaf nodes is 2, in the sequence given below. The order of internal nodes is the maximum number of tree pointers in each node, and the order of leaf nodes is the maximum number of data items that can be stored in it. The B+ - tree is initially empty.

10, 3, 6, 8, 4, 2, 1

The maximum number of times leaf nodes would get split up as a result of these insertions is

(A) 2 (B) 3 (C) 4 (D) 5

45. Let R and S be relational schemes such that R={a,b,c} and S={c}. Now consider the following queries on the database:

I. $\pi_{R-S}(r) - \pi_{R-S}\left(\pi_{R-S}(r) \times s - \pi_{R-S,S}(r)\right)$

II. $\left\{t \mid t \in \pi_{R-S}(r) \wedge \forall u \in s\left(\exists v \in r\left(u = v[s] \wedge t = v[R-S]\right)\right)\right\}$

III. $\left\{t \mid t \in \pi_{R-S}(r) \wedge \forall v \in r\left(\exists u \in s\left(u = v[s] \wedge t = v[R-S]\right)\right)\right\}$

IV Select R.a, R.b
From R,S
Where R.c=S.c

Which of the above queries are equivalent?

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

46. In the RSA public key cryptosystem, the private and public keys are (e,n) and (d,n) respectively, where n=p*q and p and q are large primes. Besides, n is public and p and q are private. Let M be an integer such that 0<M<n and $\phi(n) = (p-1)(q-1)$. Now consider the following equations.

I $M' = M^e \bmod n$
$M = (M')^d \bmod n$

II. $ed \equiv 1 \bmod n$

III. $ed \equiv 1 \bmod \phi(n)$

IV. $M' = M^e \bmod \phi(n)$
$M = (M')^d \bmod \phi(n)$

Which of the above equations correctly represent RSA cryptosystem?

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

47. 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 millisecond. 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

48. Let G(x) be the generator polynomial used for CRC checking. What is the condition that should be satisfied by G(x) to detect odd number of bits in error?

(A) G(x) contains more than two terms

(B) G(x) does not divide $1+x^k$, for any k not exceeding the frame length

(C) 1+x is a factor of G(x)

(D) G(x) has an odd number of terms.

49. Which of the following statements are TRUE?

I The context diagram should depict the system as a single bubble.

II External entities should be identified clearly at all levels of DFDs.

III Control information should not be represented in a DFD.

IV A data store can be connected either to another data store or to an external entity.

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

50. Consider the following statements about the cyclomatic complexity of the control flow graph of a program module. Which of these are TRUE?

I. The cyclomatic complexity of a module is equal to the maximum number of linearly independent circuits in the graph.

II. The cyclomatic complexity of a module is the number of decisions in the module plus one, where a decision is effectively any conditional statement in the module.

III. The cyclomatic complexity can also be used as a number of linearly independent paths that should be tested during path coverage testing.

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

Common Data Questions: 51 & 52

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 0^{th} sector is addressed as $\langle 0,0,0 \rangle$, the 1^{st} sector as $\langle 0,0,1 \rangle$, and so on

51. The address <400, 16, 29> corre4sponds tp sector number:

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

52. The address of the 1039^{th} sector is

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

Common Data Questions: 53 & 54

A sub-sequence of a given sequence is just the given sequence with some elements (possibly none or all) left out. We are given two sequences X[m] and Y[n] of lengths m and n, respectively, with indexes of X and Y starting from 0.

53. We wish to find the length of the longest common sub-sequence (LCS) of X[m] and Y[n] as l(m,n), where an incomplete recursive definition for the function l(i,j) to compute the length of the LCS of X[m] and Y[n] is given below:

$l(i,j) = 0$, if either i=0 or j=0
= expr1, if i,j>0 and $X[i-1] = Y[j-1]$
= expr2, if i,j>0 and $X[i-1] = Y[j-1]$

Which one of the following options is correct?

(A) $expr1 \equiv l(i-1,j)+1$ (B) $expr1 \equiv l(i,j-1)$

(C) $expr2 \equiv \max(l(i-1,j),\ l(i,j-1))$ (D) $expr2 \equiv \max(l(i-1,j-1),\ l(i,j))$

54. The values of l(i,j) could be obtained by dynamic programming based on the correct recursive definition of l(i,j) of the form given above, using an array L[M,N], where M = m+1 and N=n+1, such that L[i,j] = l(i,j).

Which one of the following statements would be TRUE regarding the dynamic programming solution for the recursive definition of l(i,j)?

(A) All elements L should be initialized to 0 for the values of l(i,j) to be properly computed.

(B) The values of l(i,j) may be computed in a row major order or column major order of L(M,N).

(C) The values of l(i,j) cannot be computed in either row major order or column major order of L(M,N).

(D) L[p,q] needs to be computed before L[r,s] if either p<r or q<s.

Common Data Questions: 55 & 56

Consider the following relational schema:

Suppliers(sid:integer, sname:string, city:string, street:string)
Parts(pid:integer, pname:string, color:string)
Catalog(sid:integer, pid:integer, cost:real)

55. Consider the following relational query on the above database:

```
SELECT      S.sname
FROM        Suppliers S
WHERE S.sid NOT IN (SELECT C.sid
                    FROM Catalog C
                    WHERE C.pid NOT (SELECT  P.pid
                                     FROM    Parts P
                                     WHERE P.color<> 'blue'))
```

Assume that relations corresponding to the above schema are not empty. Which one of the following is the correct interpretation of the above query?

(A) Find the names of all suppliers who have supplied a non-blue part.

(B) Find the names of all suppliers who have not supplied a non-blue part.

(C) Find the names of all suppliers who have supplied only blue parts.

(D) Find the names of all suppliers who have not supplied only blue parts.

56. Assume that, in the suppliers relation above, each supplier and each street within a city has a unique name, and (sname, city) forms a candidate key. No other functional dependencies are implied other than those implied by primary and candidate keys. Which one of the following is TRUE about the above schema?

(A) The schema is in BCNF

(B) The schema is in 3NF but not in BCNF

(C) The schema is in 2NF but not in 3NF

(D) The schema is not in 2NF

Linked Answer Questions: Q.57 to Q.60 Carry Two Marks Each

Statement for Linked Answer Questions: 57 & 58

Frames of 1000 bits are sent over a 10^6 bps duplex link between two hosts. The propagation time is 25ms. Frames are to be transmitted into this link to maximally pack them in transit (within the link).

57. What is the minimum number of bits (l) that will be required to represent the sequence numbers distinctly? Assume that no time gap needs to be given between transmission of two frames.

(A) l=2 (B) l=3 (C) l=4 (D) l=5

58. Suppose that the sliding window protocol is used with the sender window size of 2^l, where l is the number of bits identified in the earlier part and acknowledgements are always piggy backed. After sending 2^l frames, what is the minimum time the sender will have to wait before starting transmission of the next frame? (Identify the closest choice ignoring the frame processing time.)

(A) 16ms (B) 18ms (C) 20ms (D) 22ms

Statement for Linked Answer Questions: 59 & 60

Consider a binary max-heap implemented using an array.

59. Which one of the following array represents a binary max-heap?

(A) {25,12,16,13,10,8,14} (B) {25,14,13,16,10,8,12}

(C) {25,14,16,13,10,8,12} (D) {25,14,12,13,10,8,16}

60. What is the content of the array after two delete operations on the correct answer to the previous question?

(A) {14,13,12,10,8} (B) {14,12,13,8,10}

(C) {14,13,8,12,10} (D) {14,13,12,8,10}