1. Let p, q, r, s represent the following propositions.
p: $x \in \{8, 9, 10, 11, 12\}$
q: x is a composite number
r: x is a perfect square
s: x is a prime number
The integer $x \geq 2$ which satisfies $\neg((p \Rightarrow q) \wedge (\neg r \vee \neg s))$ is
A. 9 B. 11
C. 25 D. 32

2. Let an be the number of n-bit strings that do NOT contain two consecutive 1s. Which one of the following is the recurrence relation for an?
A. $a_n = a_{n-1} + 2a_{n-2}$
B. $a_n = a_{n-1} + 2a_{n-2}$
C. $a_n = a_{n-1} + 2a_{n-2}$
D. $a_n = a_{n-1} + 2a_{n-2}$

3. $\lim_{x \to 4} \frac{\sin(x-4)}{x-4} =$ ____________.
A. 0
B. 1
C. 2
D. 3

4. A probability density function on the interval [a, 1] is given by $1/x^2$ and outside this interval the value of the function is zero. The value of a is_________.
A. 0.5
B. 0.7
C. 0.8
D. 0.2

5. Two eigen values of a 3×3 real matrix P are $(2+\sqrt{-1})$ and 3. The determinant of P is _________.
A. 08
B. 15
C. 25
D. 35

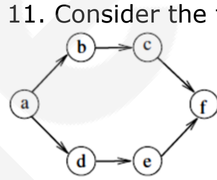
6. Consider the Boolean operator # with the following properties:
x # 0 = x, x # 1 = x , x # x = 0 and x # x = 1. Then x # y is equivalent to
A. $x\bar{y} + \bar{x}y$ B. $x\bar{y} + \bar{x}\bar{y}$
C. $\bar{x}y + xy$ D. $xy + \bar{x}\bar{y}$

7. The 16-bit 2's complement representation of an integer is 1111 1111 1111 0101; its decimal representation is _________.
A. 9
B. -9
C. 11
D. -11

8. We want to design a synchronous counter that counts the sequence 0-1-0-2-0-3 and then repeats. The minimum number of J-K flip-flops required to implement this counter is ________.
A. 2
B. 3
C. 4
D. 5

9. A processor can support a maximum memory of 4 GB, where the memory is word-addressable (a word consists of two bytes). The size of the address bus of the processor is at least __________ bits.
A. 21
B. 25
C. 31
D. 35

10. A queue is implemented using an array such that ENQUEUE and DEQUEUE operations are performed efficiently. Which one of the following statements is CORRECT (n refers to the number of items in the queue)?
A. Both operations can be performed in O(1) time
B. At most one operation can be performed in O(1) time but the worst case time for the other operation will be $\Omega(n)$
C. The worst case time complexity for both operations will be $\Omega(n)$
D. Worst case time complexity for both operations will be $\Omega(\log n)$

11. Consider the following directed graph:


The number of different topological orderings of the vertices of the graph is __________.
A. 3
B. 4
C. 5
D. 6

12. Consider the following C program.
```
void f(int, short);
void main()
{
int i = 100;
short s = 12;
short *p = &s;
___________; // call to f()
}
```
Which one of the following expressions, when placed in the blank above, will NOT result in a type checking error?
A. $f(s, *s)$ B. $i = f(i, s)$
C. $f(i, *s)$ D. $f(i, *p)$

13. The worst case running times of Insertion sort, Merge sort and Quick sort, respectively, are:
A. $\Theta(n \log n), \Theta(n \log n)$, and $\Theta(n^2)$
B. $\Theta(n^2), \Theta(n^2)$ and $\Theta(n \log n)$
C. $\Theta(n^2), \Theta(n \log n)$, and $\Theta(n \log n)$

D. $\Theta(n^2), \Theta(n \log n)$, and $\Theta(n^2)$

14. Let G be a weighted connected undirected graph with distinct positive edge weights. If every edge weight is increased by the same value, then which of the following statements is/are TRUE?
P : Minimum spanning tree of G does not change
Q : Shortest path between any pair of vertices does not change
A. P only B. Q only
C. Neither P nor Q D. Both P and Q

15. Consider the following C program.

```
#include<stdio.h>
void mystery(int *ptra, int *ptrb) {
int *temp;
temp = ptrb;
ptrb = ptra;
ptra = temp;
}
int main() {
int a=2016, b=0, c=4, d=42;
mystery(&a, &b);
if (a < c)
     mystery(&c, &a);
mystery(&a, &d);
printf("%d\n", a);
}
```

The output of the program is _______.
A. 201
B. 2016
C. 016
D. 6

16. Which of the following languages is generated by the given grammar?
$S \rightarrow aS \mid bS \mid \varepsilon$
A. $\{a^n b^m \mid n, m \geq 0\}$
B. $\{w \in \{a,b\}^* \mid w$ has equal number of a's and b's$\}$
C. $\{a^n \mid n \geq 0\} \cup \{b^n \mid n \geq 0\} \cup \{a^n b^n \mid n \geq 0\}$
D. $\{a, b\}^*$

17. Which of the following decision problems are undecidable?
I. Given NFAs N_1 and N_2, is $L(N_1) \cap L(N_2) = \Phi$?
II. Given a CFG $G = (N, \Sigma, P, S)$ and a string $x \in \Sigma^*$, does $x \in \Sigma^*, L(G)$?
III. Given CFGs G1 and G2, is $L(G1) = L(G2)$?
IV. Given a TM M, is $L(M) = \Phi$?
A. I and IV only B. II and III only
C. III and IV only D. II and IV only

18. Which one of the following regular expressions represents the language: the set of all binary strings having two consecutive 0s and two consecutive 1s?
A. $(0+1)^*0011(0+1)^*+(0+1)^*1100(0+1)^*$
B. $(0+1)^*(00(0+1)^*11+11(0+1)^*00)(0+1)^*$
C. $(0+1)^*00(0+1)^*+(0+1)^*11(0+1)^*$
D. $00(0+1)^*11+11(0+1)^*00$

19. Consider the following code segment.
$x = u - t;$
$y = x * v;$
$x = y + w;$
$y = t - z;$
$y = x * y;$
The minimum number of total variables required to convert the above code segment to static single assignment form is _________.
A. 10
B. 6
C. 7
D. 9

20. Consider an arbitrary set of CPU-bound processes with unequal CPU burst lengths submitted at the same time to a computer system. Which one of the following process scheduling algorithms would minimize the average waiting time in the ready queue?
A. Shortest remaining time first
B. Round-robin with time quantum less than the shortest CPU burst
C. Uniform random
D. Highest priority first with priority proportional to CPU burst length

21. Which of the following is NOT a super key in a relational schema with attributes V, W , X , Y , Z and primary key V Y ?
A. V XY Z B. V W X Z
C. V W XY D. V W XY Z

22. Which one of the following is NOT a part of the ACID properties of database transactions?
A. Atomicity
B. Consistency
C. Isolation
D. Deadlock-freedom

23. A database of research articles in a journal uses the following schema. (VOLUME, NUMBER, STARTPAGE, ENDPAGE, TITLE, YEAR, PRICE)
The primary key is (VOLUME, NUMBER, STARTPAGE, ENDPAGE) and the following functional dependencies exist in the schema.
(VOLUME, NUMBER, STARTPAGE, ENDPAGE) → TITLE
(VOLUME, NUMBER → YEAR
(VOLUME, NUMBER, STARTPAGE, ENDPAGE) → PRICE
The database is redesigned to use the following schemas. (VOLUME, NUMBER, STARTPAGE, ENDPAGE, TITLE, PRICE) (VOLUME, NUMBER, YEAR)
Which is the weakest normal form that the new database satisfies, but the old one does not?
A. 1NF B. 2NF
C. 3NF D. BCNF

24. Which one of the following protocols is NOT used to resolve one form of address to another one?
A. DNS B. ARP
C. DHCP D. RARP

25. Which of the following is/are example(s) of stateful application layer protocols?
(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

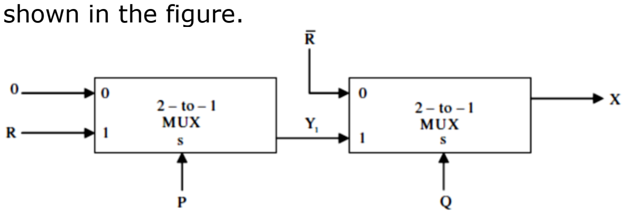
26. The coefficient of x^{12} in $\left(x^3 + x^4 + x^5 + x^6 + \ldots\right)^3$ is ____.
A. 10
B. 15
C. 20
D. 25

27. Consider the recurrence relation $a_1 = 8, a_n = 6n^2 + 2n + a_{n-1}$. Let $a_{99} = K \times 10^4$. The value of K is ___________.
A. 99 B. 198
C. 234 D. 324

28. A function $f : N^+ \to N^+$, defined on the set of positive integers N^+, satisfies the following properties
$f(n) = f(n/2)$ if n is even
$f(n) = f(n+5)$ if n is odd
Let $R = \{i \mid \exists j : f(j) = i\}$ be the set of distinct values that f takes. The maximum possible size of R is _____________.
A. 2
B. 3
C. 4
D. 5

29. Consider the following experiment.
Step 1. Flip a fair coin twice.
Step 2. If the outcomes are (TAILS, HEADS) then output Y and stop.
Step 3. If the outcomes are either (HEADS, HEADS) or (HEADS, TAILS), then output N and stop.
Step 4. If the outcomes are (TAILS, TAILS), then go to Step 1.
The probability that the output of the experiment is Y is (up to two decimal places) ___________.
A. 0.33 B. 0.14
C. 0.52 D. 0.26

30. Consider the two cascaded 2-to-1 multiplexers as shown in the figure.



The minimal sum of products form of the output X is

A. $\bar{P}\bar{Q} + PQR$ B. $\bar{P}Q + QR$
C. $PQ + \bar{P}\bar{Q}R$ D. $\bar{Q}\bar{P} + PQR$

31. The size of the data count register of a DMA controller is 16 bits. The processor needs to transfer a file of 29,154 kilobytes from disk to main memory. The memory is byte addressable. The minimum number of times the DMA controller needs to get the control of the system bus from the processor to transfer the file from the disk to main memory is ___________.
A. 312
B. 456
C. 512
D. 634

32. The stage delays in a 4-stage pipeline are 800, 500, 400 and 300 picoseconds. The first stage (with delay 800 picoseconds) is replaced with a functionally equivalent design involving two stages with respective delays 600 and 350 picoseconds. The throughput increase of the pipeline is __________ percent.
A. 3.33
B. 33.33
C. 42.33
D. 2.33

33. Consider a carry look ahead adder for adding two n-bit integers, built using gates of fan-in at most two. The time to perform addition using this adder is
A. $\Theta(1)$ B. $\Theta(\log(n))$
C. $\Theta(\sqrt{n})$ D. $\Theta(n)$

34. The following function computes the maximum value contained in an integer array p[ ] of size $n (n >= 1)$.

```
int max(int *p, int n) {
    int a=0, b=n-1;
    while ( __________ ) {
    if (p[a] <= p[b]) { a = a+1; }
    else        { b = b-1; }
    }
    return p[a];
}
```

The missing loop condition is
A. $a! = n$ B. $b! = 0$
C. $b > (a+1)$ D. $b! = a$

35. What will be the output of the following C program?

```
void count(int n){
    static int d=1;
    printf("%d", n); printf("%d", d);
    d++;
    if(n>1) count(n-1);
    printf("%d ", d);
}
void main(){
count(3);
}
```

A. 3 1 2 2 1 3 4 4 4
B. 3 1 2 1 1 1 2 2 2
C. 3 1 2 2 1 3 4
D. 3 1 2 1 1 1 2

36. What will be the output of the following pseudo-code when parameters are passed by reference and dynamic scoping is assumed?

```
a=3;
void n(x) {x = x * a; print(x);}
void m(y) {a = 1; a = y - a; n(a); print(a);}
void main() {m(a);}
```

A. 6, 2 B. 6, 6
C. 4, 2 D. 4, 4

37. An operator delete (i) for a binary heap data structure is to be designed to delete the item in the i-th node. Assume that the heap is implemented in an array and i refers to the i-th index of the array. If the heap tree has depth d (number of edges on the path from the root to the farthest leaf), then what is the time complexity to re-fix the heap efficiently after the removal of the element?
A. O(1)
B. O(d) but not O(1)
C. O(2d) but not O(d)
D. O(d 2d) but not O(2d)

38. Consider the weighted undirected graph with 4 vertices, where the weight of edge {i, j} is given by the entry W_{ij} in the matrix W.

$$W = \begin{bmatrix} 0 & 2 & 8 & 5 \\ 2 & 0 & 5 & 8 \\ 8 & 5 & 0 & x \\ 5 & 8 & x & 0 \end{bmatrix}$$

The largest possible integer value of x, for which at least one shortest path between some pair of vertices will contain the edge with weight x is ___________.
A. 12
B. 13
C. 14
D. 15

39. Let G be a complete undirected graph on 4 vertices, having 6 edges with weights being 1, 2, 3, 4, 5, and 6. The maximum possible weight that a minimum weight spanning tree of G can have is ____________.
A. 4
B. 5
C. 6
D. 7

40. G = (V, E) is an undirected simple graph in which each edge has a distinct weight, and e is a particular edge of G. Which of the following statements about the minimum spanning trees (MSTs) of G is/are TRUE?
I. If e is the lightest edge of some cycle in G, then every MST of G includes e
II. If e is the heaviest edge of some cycle in G, then every MST of G excludes e
A. I only
B. II only
C. both I and II
D. neither I nor II

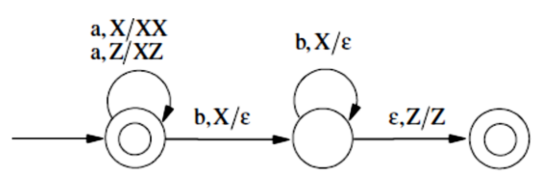
41. Let Q denote a queue containing sixteen numbers and S be an empty stack. Head(Q) returns the element at the head of the queue Q without removing it from Q. Similarly Top(S) returns the element at the top of S without removing it from S. Consider the algorithm given below.
while Q is not Empty do

```
    if S is Empty OR Top(S) ≤ Head(Q) then
      x := Dequeue(Q);
          Push(S, x);
    else
          x := Pop(S);
          Enqueue(Q, x);
    end
end
```

The maximum possible number of iterations of the while loop in the algorithm is _________.
A. 134
B. 256
C. 512
D. 634

42. Consider the following context-free grammars:
G1: $S \rightarrow aS|B$, $B \rightarrow b|bB$
G2: $S \rightarrow aA|bB$, $A \rightarrow aA|B|\varepsilon$, $B \rightarrow bB|\varepsilon$
Which one of the following pairs of languages is generated by G1 and G2, respectively?
A. $\{a^m b^n \mid m > 0 \text{ or } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ and } n > 0\}$
B. $\{a^m b^n \mid m > 0 \text{ and } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ or } n \leq 0\}$
C. $\{a^m b^n \mid m \geq 0 \text{ or } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ and } n > 0\}$
D. $\{a^m b^n \mid m \geq 0 \text{ or } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ or } n > 0\}$

43. Consider the transition diagram of a PDA given below with input alphabet $\sum = \{a, b\}$ and stack alphabet $\Gamma = \{X, Z\}$. Z is the initial stack symbol. Let L denote the language accepted by the PDA.



Which one of the following is TRUE?
A. $L = \{a^n b^n \mid n \geq 0\}$ and is not accepted by any finite automata
B. $L = \{a^n \mid n \geq 0\} \cup \{a^n b^n \mid n \geq 0\}$ and is not accepted by any deterministic PDA
C. L is not accepted by any Turing machine that halts on every input
D. $L = \{a^n \mid n \geq 0\} \cup \{a^n b^n \mid n \geq 0\}$ and is deterministic context-free

44. Let X be a recursive language and Y be a recursively enumerable but not recursive language.
Let W and Z be two languages such that Y reduces to W, and Z reduces to X (reduction means the standard many-

one reduction). Which one of the following statements is TRUE?
A. W can be recursively enumerable and Z is recursive.
B. W can be recursive and Z is recursively enumerable.
C. W is not recursively enumerable and Z is recursive.
D. W is not recursively enumerable and Z is not recursive.

45. The attributes of three arithmetic operators in some programming language are given below.

Operator	Precedence	Associativity	Arity
+	High	Left	Binary
−	Medium	Right	Binary
*	Low	Left	Binary

The value of the expression $2-5+1-7*3$ in this language is ____________.
A. 3
B. 6
C. 9
D. 12

46. Consider the following Syntax Directed Translation Scheme (SDTS), with non-terminals {S, A} and terminals {a, b}.

$S \to aA \{print\ 1\}$

$S \to a \quad \{print\ 2\}$

$A \to Sb \{print\ 3\}$

Using the above SDTS, the output printed by a bottom-up parser, for the input aab is:
A. 1 3 2 B. 2 2 3
C. 2 3 1 D. syntax error

47. 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.
A. 384
B. 423
C. 512
D. 643

48. 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 ___________.
A. 346
B. 423
C. 545
D. 623

49. Consider a computer system with ten physical page frames. The system is provided with an access sequence $(a_1, a_2, \ldots a_{20}, a_1, a_2, \ldots\ldots a_{20})$, where 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 ___________.
A. 0
B. 1
C. 2
D. 3

50. Consider the following proposed solution for the critical section problem. There are n processes: $P_0 \ldots P_{n-1}$.
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 Pi:
do {
    c[i]=1; t[i] = pmax(t[0],...,t[n-1])+1;
    c[i]=0;
    for every j = i in {0,. . .,n-1} {
      while (c[j]);
      while (t[j] != 0 && t[j]<=t[i]);
    }
    Critical Section;
    t[i]=0;
    Remainder Section;
} while (true);
```

Which one of the following is TRUE about the above solution?
A. At most one process can be in the critical section at any time
B. The bounded wait condition is satisfied
C. The progress condition is satisfied
D. It cannot cause a deadlock

51. Consider the following two phase locking protocol. Suppose a transaction T accesses (for read or write operations), a certain set of objects $\{O_1, \ldots\ldots, O_k\}$. This is done in the following manner:
Step 1. T acquires exclusive locks to $O1, \ldots\ldots, Ok$ in increasing order of their addresses.
Step 2. The required operations are performed.
Step 3. All locks are released.
This protocol will
A. guarantee serializability and deadlock-freedom
B. guarantee neither serializability nor deadlock-freedom
C. guarantee serializability but not deadlock-freedom
D. guarantee deadlock-freedom but not serializability

52. Consider that B wants to send a message m that is digitally signed to A. Let the pair of private and public keys for A and B be denoted by K_x^- and K_x^+ for $x = A, B$, respectively. Let $K_x(m)$ represent the operation of encrypting m with a key Kx and H (m) represent the message digest. Which one of the following indicates the CORRECT way of sending the message m along with the digital signature to A?

A. $\{m, K_B^+(H(m))\}$

B. $\{m, K_B^-(H(m))\}$

C. $\{m, K_A^-(H(m))\}$

D. $\{m, K_A^+(H(m))\}$

53. An IP datagram of size 1000 bytes arrives at a router. The router has to forward this packet on a link whose MTU (maximum transmission unit) is 100 bytes. Assume that the size of the IP header is 20 bytes.
The number of fragments that the IP datagram will be divided into for transmission is ________.
A. 12
B. 13
C. 15
D. 16

54. 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. 0.4
B. 1.2
C. 2.4
D. 2.9

55. A sender uses the Stop-and-Wait ARQ protocol for reliable transmission of frames. Frames are of size 1000 bytes and the transmission rate at the sender is 80 Kbps (1Kbps = 1000 bits/second). Size of an acknowledgement is 100 bytes and the transmission rate at the receiver is 8 Kbps. The one-way propagation delay is 100 milliseconds.
Assuming no frame is lost, the sender throughput is ___________ bytes/second.
A. 1200
B. 2500
C. 3100
D. 4000

***