MOTILAL NEHRU NATIONAL INSTITUTE OF TECHNOLOGY ALLAHABAD
Department of Electronics & Communication Engineering
Mid-Semester Examination (Even Sem 2016-17)
B. Tech. IV Semester, CSE + IT
Course: Communication Foundations (EC-1405)

Max Marks:20 **Time: 1:30 Hours**

J. Anushree prasad

Note: Attempt all the questions.
Assume suitable data if required.

Q1. **(a)** Draw block diagram of a basic communication system and explain working of each block of the system. 2

(b) Define (with suitable expressions) unit step functions, impulse functions, energy signals and power signals. 3

Q2. **(a)** Define auto-correlation and cross-correlation functions with suitable examples. 2.5

(b) Find E_x and E_y, the energies of the signals x(t) and y(t) respectively, given in Fig. 2(b) shown below. Sketch the signals x(t)+y(t) and show that energy of either of these two signals is E_x+E_y. 2.5

Fig. Q2(b)

Q3. **(a)** Draw the line spectrum and phase spectrum of 2

$w(t) = 7 - 10\cos(40\pi t - 60^{\circ}) + 4\sin(120\pi t)$

(b) Find the Fourier series for the periodic wave w(t), shown in Fig. Q. 3(b). Also draw the amplitude and phase spectrums 3

Q4. **(a)** State and verify with an example, the Duality property of Fourier transform representation. 2.5

(b) Define Gate function and find its Fourier transform. Also, draw the amplitude and phase spectrums. 2.5

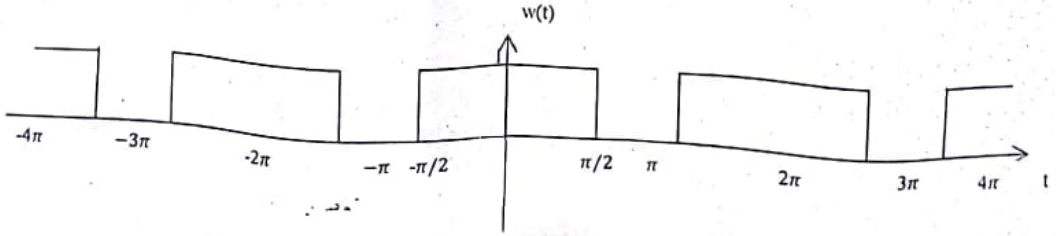

Fig. Q3(b)

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Motilal Nehru National Institute of Technology Allahabad
Department of Computer Science and Engineering
Mid-Sem Examination 2016-17
B.Tech 4th semester(CS/IT), Course Code: CS1402
Course Name: Graph Theory and Combinatorics

Time: 1.5 Hour **MM: 20.**

Note: Attempt all questions and justify your answers with the proper reason.

1) Consider an undirected graph G where self-loops are not allowed. The vertex set of G is $\{(i,j): 1 \leq i \leq 12, 1 \leq j \leq 12\}$. There is an edge between (a, b) and (c, d) if $|a - c| \leq 1$ and $|b - d| \leq 1$. What is the number of edges in this graph? [3]

2) Explain under which condition a complete bipartite graph is (i) regular graph (ii) complete graph. Also answers the following: [1+1+1+1=4]
   (iii) How many complete bipartite graphs have k vertices?
   (iv) What is the maximum number of edges in a simple bipartite graph with k vertices?

3) Every Arbitrarily Traceable graphs is Euler graph but every Euler graphs is not Arbitrarily Traceable graphs discuss it with examples. [2]

4) The complement G' of a graph G has the same vertex set as G, but xy is an edge in G' if and only if xy is not an edge in G. Show: [2+1=3]
   a) A graph G is called self-complementary if G and G' are isomorphic. Show: if a graph G on n vertices is self-complementary, then either n or n − 1 is divisible by 4.
   b) A cycle on n vertices is isomorphic to its complement. What is value of n? Also draw the diagram for it.

5) The graph Fig(i) shown below has 8 edges with distinct integer edge weights. The minimum spanning tree (MST) is of weight 36 and contains the edges: {(A, C), (B, C), (B, E), (E, F), (D, F)}. The edge weights of only those edges which are in the MST are given in the figure shown below. What is the Minimum possible sum of weights of all 8 edges of this graph? [3]

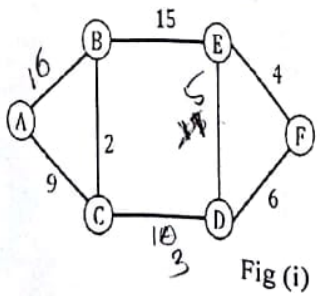

Fig (i)

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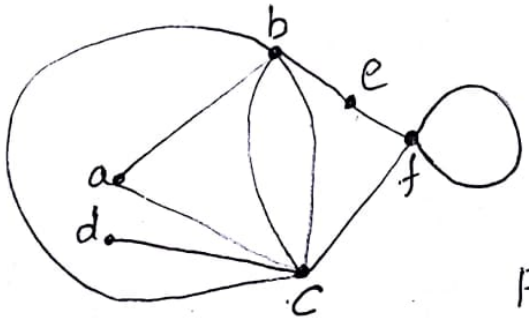
6) Show $K_{3,4}$ is non-planner and find its crossings. Let G be a connected planar graph with 10 vertices. If the number of edges on each face is three, then find the number of edges in G. [1+1+1=3]

7) Draw Geometric Dual of graph 'G' i.e G*. Fig(ii)[1+1=2]
Also show relationship between:
e, n, f, r, μ of G to (e^*,n^*, f^*, r^*, μ^*) of G*
Where, [e= edges, n= no. of vertices, r=rank, f=region, μ=nullity]



Fig(ii)

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J. Anushree Prasad

Department of Computer Science & Engineering,
Motilal Nehru National Institute of Technology Allahabad.
Mid Semester Examination 2016-17 [B.Tech. CS+IT]

Subject: Analysis of Algorithms (CS 1401) **Duration:** 1.5 HRS **Max. Marks:** 20

Note: Be specific and to the point in your answers. Make assumptions wherever necessary and quote it. All questions are compulsory. Neat answers, without cuttings will be appreciated. It is advisable to design the solution in rough before writing the final answers. Answer the questions serially.

Q1. **[3+3]** Towers-of-Hanoi is an interesting problem in which there are three towers: A, B, and C. Initially, n discs are stacked on tower A, and each disc is smaller than the one below it. The object of the game is to move the stack of discs to tower B in the same order. The third tower is used as intermediate storage. There are two rules for moving the discs: Only one disc can be moved at a time from the top of one tower to the top of another, and a larger disc can never be placed on top of a smaller one. The recursive procedure for solving Towers-of-Hanoi is:

```
Towers (A; B; n; C) {      //Move n disc from tower A to B. Use C as temp storage.
  if (n == 1)
        MOVE (A;B) //Move one disc from A to B
  else {
        Towers (A; C; n-1; B)
        MOVE (A;B)
        Towers (C; B; n -1;A)
  }
}
```

In context of Towers-of-Hanoi problem answer the following questions:

a. Let $f(n)$ be the number of single-disc moves this algorithm makes to solve the n-disc problem. Write a recurrence for $f(n)$.

b. Derive the complexity notation for $f(n)$.

Q2. **[3+3]** Consider the recurrence $T(n)$, where n is a power of 2: $T(n) = \begin{cases} 0 & \text{if } n = 1 \\ 2T\left(\frac{n}{2}\right) + log_2 n & \text{if } n > 1 \end{cases}$

and answer the following questions:

a. Use master method and find a working solution.

b. Prove by induction that the exact solution is of the form: $T(n) = An + Blog_2 n + C$ and thus find the constants A, B and C.

Q3. **[3+3+2]** In the context of the function *fun()*, answer the following questions:

a. State the time complexity of *fun()*, in terms of θ notation.

b. Give a precise count on the number of multiplications used by *fun()*.

c. What is the objective of *fun()*?

```
int fun( int bb , int ee ) {
  int acc = 1 ;
  int e = ee ;
  int b = bb ;
  if ( e == 0) { return 1 ;}
  while ( e != 1) {
      if ( e % 2 == 1) { acc *= b ;}
      b *= b;
      e /= 2 ;
  }
  return acc * b ;
}
```

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Department of Computer Science & Engineering,
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B.Tech IV Semester CS
MID Semester Examination 2017

Subject: Automata Theory
Duration: 1:30 HRS

Paper code: CS 1404
Max. Marks: 20

Note: Attempt all questions. Be specific in your answers. Make assumptions wherever necessary and quote it. Do all the questions serially.

1. Prove or disprove each of the following statements: [3]
   (a) It is possible that the intersection of an infinite number of regular languages is not regular.
   (b) Every subset of a regular language is regular.
   (c) Let L4 = L1L2L3. If L1 and L2 are regular and L3 is not regular, it is possible that L4 is regular.

2. If L1 and L2 are languages, define a new language: INTERLACE $(L_1, L_2) = \{w_1v_1w_2v_2w_3v_3 \dots \dots \dots w_nv_n |\ w_1w_2w_3 \dots \dots \dots w_n \in L_1, v_1v_2v_3 \dots \dots \dots v_n \in L_2\}$. for example, if abc $\in L_1$ and 123 $\in L_2$, then a1b2c3 $\in$ INTERLACE (L_1, L_2). Show that if L_1 and L_2 are regular languages, then INTERLACE (L1, L2) is a regular language. [3]

3. (a) Construct a mealy machine for binary adder and convert into the equivalent moore machine [1]

   (b) Construct a mealy machine which take binary input and produce 2's compliment as output. Assume that string is read from LSB to MSB and end carry is discarded. As a sum of present and previous bit. [1]

4. (a) Design Deterministic Finite Automata that recognize
   $L = \{x \in \{(0,1)^*: |x| \geq 3 \text{ and the 3 rd symbol from the right is } x = 1\}$ [2]

   (b) Suppose L is regular, $L \subseteq \{0,1\}^*$, we define new language, $L_1 = \{y \in \{0,1\}^* | \text{There is an } x \in L, \text{exactlly one bit of which is flipped to obtain } y\}$ is also regular. [2]

5. (a) Using the pumping lemma show that the following language is not regular. [2]

   L(M) = {w = vz : v∈{a,b}* and z = all a's in v replaced by b's and vice versa}

   (b) Construct the CFG, G, for the language. [2]

   L(G) = $\{a^i b^j c^k$: i = j or i = k or j =k$\}$

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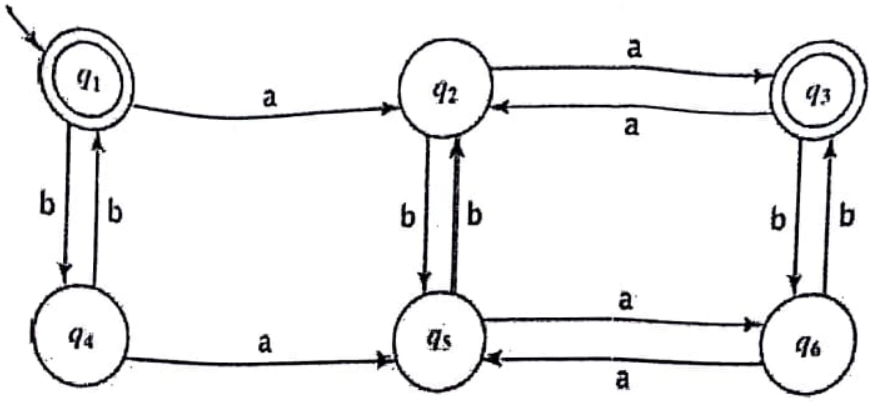
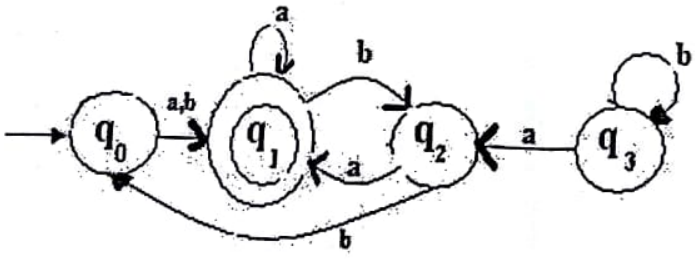
6. (a) Let M be the following DFA. [2]



Minimize M by set partitioning

(b) Obtain regular expression for the language accepted by following automata. [2]



Anushree Prasad T

MOTILAL NEHRU NATIONAL INSTITUTE OF TECHNOLOGY ALLAHABAD
Department of Electronics & Communication Engineering
End-Semester Examination (Even Sem 2016-17)
B. Tech. IV Semester (EC-1405)
Course: Communication Foundations

Time: 3.00 Hours

Max Marks: 60

Note: Attempt any SIX questions. Assume suitable data if required.

Q.1. (a) Find the energy of the signal shown in Fig. 1(a). Comment on the energy of the signal for its (i) sign change, (ii) time shift, and (iii) doubling of the signal. What is the effect if the signal is multiplied by k(constant). 5

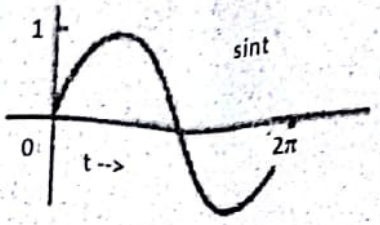


Fig. 1(a)

(b) Find the power of the periodic signal g(t), shown in Fig. 1(b). Find also the power and r.m.s. values of (i) -g(t) (ii) 2g(t) (iii) cg(t), where c is a constant. 5

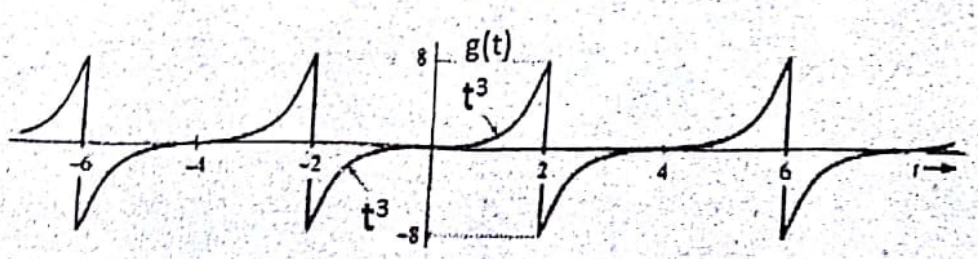


Fig. 1(b)

Q.2. (a) Find the exponential Fourier series and sketch amplitude and phase spectra for the following periodic signal shown in Fig. 2(a). 5

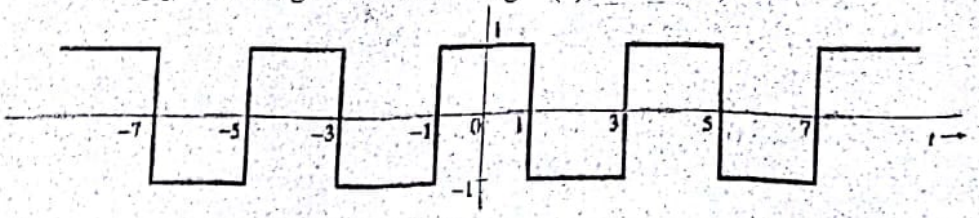


Fig. 2(a)

(b) The equation of an angle modulated voltage is $v = 10\sin(10^8 t + 3sin10^4 t)$. What form of angle modulation is this? Calculate the carrier and modulating frequencies, the modulation index, deviation, and the power radiated in a 100-Ω resistor. 5

Q.3. (a) Define AM, it modulation index and derive an expression for AM waveform in terms of modulation index. Explain with suitable block diagram, generation and demodulation of AM. 5

(b) Derive an expression for single tone FM in terms of β. What is minimum and maximum phase deviation? Draw block diagram for conversion from PM to FM and vice versa. Explain generation of single tone FM using any one method. 5

Q.4. (a) Find the Fourier Transform of g(t), given by 5

$$g(t)=\begin{cases}1 & -1<t\le 0\\ 2 & 0<t\le 1\\ 1 & 1<t\le 2\\ 0 & \text{otherwise}\end{cases}$$

Also, find Fourier Transform of g(t-1).

(b) If $g_{12}(t)= g_1(t)*g_2(t)$, show that $\frac{dg_{12}(t)}{dt} = g_1(t)*\frac{dg_2(t)}{dt} = \frac{dg_1(t)}{dt}*g_2(t)$, by using convolution and differentiation properties of Fourier Transform. 5

Q.5. (a) Explain each step with suitable examples the analog to digital conversion of a signal. 5

(b) A PCM uses a uniform quantizer followed by 7-bit binary encoder. The bit rate of the system is equal to 50×10^6 bits/sec. What is the minimum message bandwidth for which the system operates satisfactorily? 5

Q.6. (a) Explain the advantages of digital modulation schemes over analog modulation. Explain modulation and demodulation of PSK. Also, compare the ASK, FSK and PSK modulations. 5

(b) Explain pulse analog modulation techniques and write their applications. 5

Q.7. Write short notes on any **FOUR** of the following: 2.5x4

(a) Super heterodyne receiver
(b) Ground wave, sky wave and space wave propagations
(c) Properties of Fourier integrals
(d) Nyquist criterion for sampling
(e) Types of signals and systems

Prasad. J

Department of Computer Science & Engineering,
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B.Tech IV Semester CS
END Semester Examination 2017

Subject: Automata Theory
Duration: 3:00 HRS

Paper code: CS 1404
Max. Marks: 60

Note: Attempt all questions. Be specific in your answers. Make assumptions wherever necessary and quote it. ***Do all the questions serially.***

1. Are the following statements true or false? Explain your answer in each case. (In each case, a fixed alphabet Σ is assumed.) **[2X4]**
   (a) If L is accepted by a deterministic PDA, then the compliment of L, L' must be a regular.
   (b) If L is accepted by deterministic PDA, then the compliment of L, L' must be a context free.
   (c) If L is a language over the alphabet Σ and $a \in \Sigma$, define $a\backslash L = \{w \mid aw \in L\}$. If L is regular, then so is $a\backslash L$
   (d) If L1 and L2 are non regular language, then L1 U L2 is also not regular.

2. a) Design deterministic finite automata for the set of strings over the alphabet {a, b} containing at least three occurrences of three consecutive b's, overlapping permitted (e.g., the string bbbbb should be accepted.) **[2.5x3]**

   b) Let $\Sigma = \{0, 1\}$. Let L be the language that consists of strings having either 01 repeated one or more times or 010 repeated one or more times. Is L regular? Explain

   c) Construct the equivalent finite automata from the following regular grammar.
   $S \rightarrow aS \mid bA \mid b$
   $A \rightarrow aA \mid bS \mid a$

3 a) Assume that a regular language L is provided to you as a DFA M $\{Q, \Sigma, \delta, q_0, F\}$. How would you check whether L is infinite? **[2.5x3]**

b) Design a Push down Automata for accepting the string for the laguage $L = \{WW^R \mid W \in (a, b)^*\}$ by the empty stack as well as final state.

c) show that L= Palindrome over {a, b} is not regular.

4. (a) Construct a Moore machine which determines the residue mod 3 for each binary string treated as binary integer. And the convert into the corresponding mealy machine. **[2x3]**

(b) Design Finite State Machine or abstract model for binary adder

(c) Prove that the language $L = \{a^{i^2} \mid i \geq 1\}$ is not context free language.

5. (a) Consider the language L= $\{a^m b^{2n} c^{3n} d^p : p > m \text{ and } m, n \geq 1\}$ [2.5x3]
Write a context free grammar to generate L and write shortest string in L.

(b) Design a PDA for Hypertext markup language (HTML) consisting of all the tags having immediate closing tags within the <BODY> </BODY> tag. For example:

```
<HTML>
  <HEAD>
   <TITLE>
    My first web page
     </TITLE>
        </HEAD>
          <BODY>
           <B> First web page </B>
           </BODY>
 </HTML>
```

(c) Convert the following Context free Grammar into GNF

S → XY
X→ YS | b
Y → SX | a

6. (a) Prove that if L =N(P_N) for some empty stack pda $P_N = \{Q, \Sigma, \Gamma, \delta_N, q_0, Z_0, \emptyset\}$, the there is a final state pda P_F such that L =L(P_F). [2.5x3]

(b) Using the grammar
S → AB | BC
A → BA | a
B → CC | b
C → AB | a
Use the CYK algorithm to determine whether the given string "baaba" is in L(G) or not?

(c) Construct a push down automata that accept the following language.

L= $\{uawb: u \text{ and } w \in (a,b)^* \text{ and } |u| = |w|\}$

7. (a) Design A Turing Machine to perform 2"s compliment operation on binary string. [4x2]

(b) Consider the laguage L= $\{WW^R | W \in (a,b)^*\}$
(i) Design one tape turing machine to accept L
(ii) How much efficient is the two tape tuting machine as compare to one tape turing machine

8. Write Short Notes on following: [2x4]

(i)DeterminesticPDA Vs Nondeterminestic PDA ii) Universal Turing Machine

iii) Nondeterminestic Turing Machine iv) Post crospondance Problem (PCP)

J. Anushree Prasad

Department of Computer Science & Engineering
Motilal Nehru National Institute of Technology Allahabad
End Semester Examination 2016-17
Class: B. Tech 4th Semester (CS/IT) 2016-2017
Subject: Contemporary Issues in IT Code: (CS-1405)

Time: 3 Hrs

M.M.: 60 Marks
All questions are compulsory and carry equal marks.

Q1. Explain the key features that are considered for evaluating the methodologies incorporated in designing any Ontology.

Q2. Write a brief biography of four ACM Turing Award recipients in about 70 words each.

Q3. What are the characteristics of a flame graph? How flame graphs are helpful in interpreting CPU profile outputs, explain with a suitable example.

Q4. Discuss the main components of Ontology. Give two appropriate examples for each of the components.

Q5. You are working as an IT Manager in a real estate firm that builds old-age home. Give your opinion on developing a smart old-age home from an IT perspective in around 150 words.

Q6. Write short notes on:
i) Privacy Research Directions
ii) Spatial Computing
iii) Stack Tool
iv) CSR
v) Bitcoin

Motilal Nehru National Institute of Technology Allahabad
Department of Computer Science and Engineering
End-Sem Examination 2016-17
Programme- B.Tech 4th semester(CS-IT), Course Code: CS1402
Course Name: Graph Theory and Combinatorics

Time: 3 Hour MM:60.

Note: Attempt all questions

J. Anushree prasad

1) Solve following questions
   a) Prove that simple graph with n vertices and k components can have at most (n-k)(n-k+1)/2 edges.
   b) The 2^n vertices of graph G correspond to all subsets of a set of size n, for n≥6.Two vertices of G are adjacent if and only if the corresponding subsets intersect in exactly two elements. What is the number of connected components in G? [3+3=6]

2) What is the difference between matching and covering of a graph? Why dimer covering is often referred to as a perfect matching? How many perfect matchings are there in a complete graph of six vertices? [2+2+2=6]

3) Discuss the relationship between fundamental circuits and cut-sets. "With respect to a given spanning tree T, a chord c_i that determines a fundamental circuit Γ occurs in every fundamental cut-set associated with the branches in Γ and in no other", Explain it with suitable example .[2+2=4]

4) Define branch and chord in Graph G? If we have a farm consisting of six walled plots of land as shown in Fig(i) and these plots are full of water, how many walls have to be broken so that all the water can be drain out? Also make diagram after breaking the walls. [2+2=4]

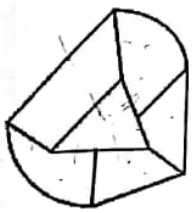
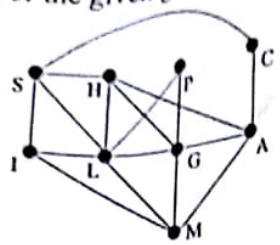


Fig (i)

5) What is Hamiltonian circuit? Twenty members of a club meet each day for lunch at round table. They decide to sit such that every member has different neighbors at each lunch. How many days can this arrangement last? [1+3=4]

6) Let G be a complete undirected graph on 6 vertices. If vertices of G are labeled, then what is the number of distinct cycles of length 4 in G? [4]

7) For the given graph fig(ii), find out



•Fig (ii)

a) Chromatic no and chromatic partitioning
b) Maximal independent set and coefficient of internal stability
c) Minimal dominating set and dominating number [2+2+2=6]

8) Derive the Chromatic polynomial for the given graph Fig (iii) (disconnected).

Fig (iii) [4]

9) Find out the complexity through recurrence relation by substitution method.

a) $T(n) = \begin{cases} T(\sqrt{n}) + 1, & n > 2 \\ a & , \quad n = 2 \end{cases}$

b) $T(n) = \begin{cases} 4T(n/2) + n^2, n > 1 \\ a \qquad\quad , \; n = 1 \end{cases}$

[3+3=6]

10) State the Pigeon-hole principle. Solve the following problem:
A bag contains 100 apples, 100 bananas, 100 oranges, and 100 pears. If I pick one piece of fruit out of the bag every minute, how long will it be before I am assured of having picked at least a dozen pieces of fruit of the same kind? [1+3=4]

11) Imagine a prison consisting of 64 cells arranged like the squares of an 8-by-8 chessboard. There are doors between all adjoining cells. A prisoner in one of the corner cells is told that he will be released, provided he can get into the diagonally opposite corner cell after passing through every other cell exactly once. Can the prisoner obtain his freedom?Explain. [4]

12) Solve following permutation and combinations.
a) How many integers between 0 and 10,000 have only one digit equal to 5.

b) A football team of 11 players is to be selected from a set of players, 5 of whom can play only in the backfield, 8 of them can only play on the line, 2 of them can play either in the backfield, or on the line. Assuming a football team has 7 men on the line and 4 men in the backfield determine the number of football teams possible. [4+4=8]

**********END**********

Department of Computer Science & Engineering
Motilal Nehru National Institute of Technology Allahabad
(End Semester Examination 2016-2017)

Subject: Analysis of Algorithms(CS1401) Duration: 3 HRS Max Marks: 60

Note: Be specific and to-the-point in your answers. Make assumptions wherever necessary and quote it. All questions are compulsory. Neat answers, without cuttings will be appreciated. It is advisable to design the solution in rough before writing the final answers. Answer the questions serially.

Q1. [15 marks] A student, studying 3 subjects (Automata, Algorithms & Networks), has to participate in a quiz. S/He has left with *4* hours only for preparation. We are given a certain probability *p*, of failing in a particular subject if S/He studies that subject for a particular number of hours.

Hours for study	Probability (p) that S/He fails		
	Automata	Algorithms	Networks
0	0.80	0.75	0.90
1	0.70	0.70	0.70
2	0.65	0.67	0.60
3	0.62	0.65	0.55
4	0.60	0.62	0.50

Example: If S/He devotes *1* hour for Automata, *1* hour for Algorithm & *2* hours for Network then his failure probability will be *.294 (= .7 * .7 * .6)*.

Finding a preparation strategy ({subject *s*, number of hours to devote for subject *s*}) is a dynamic programming problem. Give an **algorithm with its complexity analysis** so as to minimize the failure probability by finding the optimal preparation strategy.

Q2. [15 marks] Arbitrage is the use of discrepancies in currency exchange rates to transform one unit of a currency into more than one unit of the same currency. For example, suppose that *1* U.S. dollar buys *64.27* Indian Rupees, *1* Indian Rupee buys *1.73* Japanese Yen, *1* Japanese Yen buys *1.37* Sri Lankan Rupees and *1* Sri Lankan Rupee buys *0.01* U.S. Dollars. Then, by converting currencies, a trader can start with *1* U.S. dollar and buy $64.27 \times 1.73 \times 1.37 \times 0.01 \approx 1.52$ U.S. dollars, thus turning a profit of *52%*.

Suppose that we are given n currencies $c_1, c_2, \ldots, c_n$ and an $n \times n$ table of R exchange rates, such that one unit of currency c_i buys $R[i, j]$ units of currency c_j. **Give an efficient algorithm** to determine whether there exists a sequence of currencies $\langle c_{i1}, c_{i2}, \ldots, c_{ik} \rangle$ such that $R[i_1; i_2] \times R[i_2; i_3] \ldots R[i_{k-1}; i_k] \times R[i_k; i_1] > 1$. Also **analyze the running time** of your algorithm.

Q3. [6 marks] In context of Towers-of-Hanoi algorithm answer the following questions:

a. Let $f(n)$ be the number of single-disc moves this algorithm makes to solve the n-disc problem. Write a recurrence for $f(n)$.

b. Derive the complexity notation for $f(n)$.

```
Towers-of-Hanoi (A; B; n; C)
    if (n == 1)
        MOVE (A;B)
    else
        Towers-of-Hanoi (A; C; n-1; B)
        MOVE (A;B)
        Towers-of-Hanoi(C; B; n -1;A)
```

Q4. [6 marks] Answer the following questions while considering the recurrence $T(n)$, $T(n) = \begin{cases} 0 & \text{if } n = 1 \\ 2T\left(\frac{n}{2}\right) + log_2 n & \text{if } n > 1 \end{cases}$ where n is a power of 2.

a. Use master method and find a working solution.

b. Prove by induction that the exact solution is of the form: $T(n) = An + Blog_2 n + C$ and thus find the constants A, B and C.

Q5. [6 marks] How many spurious hits does the *Rabin-Karp* matcher encounter in the text $T = 3141592653589793$ while searching for pattern $P = 26$ with working modulo $q = 11$?

Q6. [6 marks] Prove that the complexity of *BUILD-MAX-HEAP* over an array of size n is $O(n)$.

Q7. [6 marks] Explain asymptotic notations and their utility in algorithm analysis.

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Department of Computer Science and Engineering
Motilal Nehru National Institute of Technology
End Semester Exam, Computer Organization (CS1403)
BTech (IT, CS) IV Semester
Time: 3 Hour, MM:60

Note: There are 5 questions. Attempt any 4. Avoid story telling. Be crisp and concise while answering questions.

1. **Pipelined Datapath**

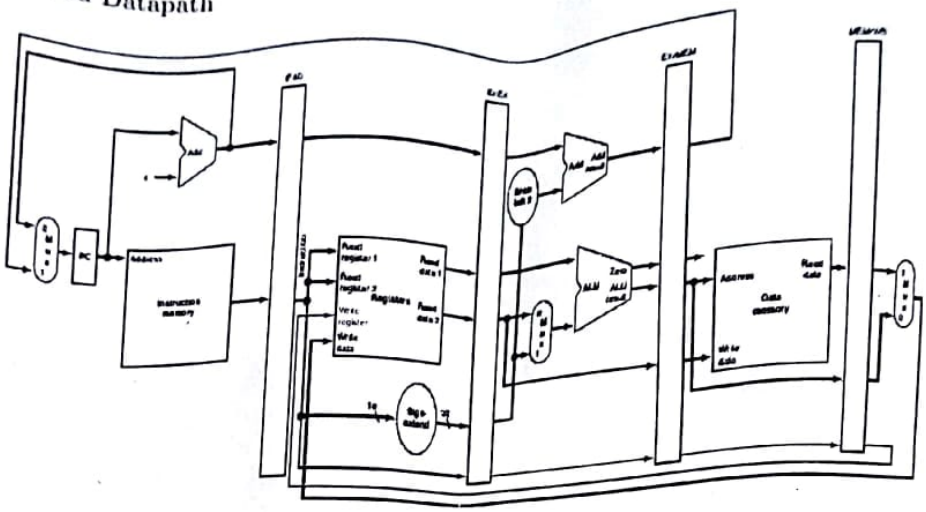

Figure 1: Schematic for Pipeline data-path

(a) Consider the execution of following instruction sequence over datapath given in Figure.1:

```
lw  $t0,  10($t1)
sw  $t3, 20($t4)
add $t5,  $t6,  $t7
sub $t8,  $t9,  $t10
```

Show and explain explicitly the contents of Pipeline Registers (IF/ID, ID/EX, EX/MEM, MEM/WB) after every clock cycle starting from clock cycle 1 to clock cycle 6.

(b) For each of the following sequences of instructions, state: (1) Whether a data hazard exists in the pipelined datapath of Figure.1 (2) If that data hazard necessarily results in a stall, and (3) Which forwarding paths (from the output of which stage to the input of which stage) are necessary to eliminate or minimize the stall.

- `lw $s0, 4($s1)`
  `addi $s2,$s0,10`
- `slt $s1,$s2,$s3`
  `sw $s1,4(4$t0)`

2. **Cache Memory:**

(a) Suppose a computer has 4-way set associative cache with 64 one word (4 byte) blocks. Given the sequence of byte addresses 8, 64, 96, 128, 64, 96, 256, 192, 24 show the final cache contents and state the numbers of cache hit and miss.

(b) Assuming a cache of 16K blocks and a 32 bit address, find the total number of sets and the total number of tag bits for caches that are direct mapped, two-way and four-way set associative, and fully associative.

(c) Draw a picture showing the organization of a 4-way set associative cache having 1K one word blocks. Show any multiplexers, comparators, gates etc. needed. Show how a 32 bit address is mapped to a cache block.

(d) Differentiate between "read miss" and "write miss" both for instruction and data wherever applicable. What are the different policies to handle them? If it is an instruction "read miss", how it is handled.

3. **Virtual Memory:**

(a) Write 100-150 words essay about your understanding of Virtual Memory.

(b) What modifications you want to make in your essay of part (a) if suppose your machine is running two Virtual Machines (VM) also.

(c) Suppose that a system has a 32-bit(4GB) virtual address space. It has 1GB of physical memory, and uses 1MB pages.(i) How many virtual pages are there in the address space? (ii) How many physical pages are there in the address space? (iii) How many bits are there in the page offset? (iv) How many bits are there in the virtual page number? (v) How many bits are there in the physical page number? (vi) What would be the size of page table?

(d) In part (c) above if you are getting the page table size bigger than physical page size, how this situation can be amicably solved?

4. **Arithmatic and other Freebies**

(a) Draw the optimized Multiplier and Divider hardware discussed in class with appropriate control signals. Observe and write the similarities between these two hardwares. How can we use the same hardware both for multiplication and division. Explain. (Hint: in these hardwares only four elements are there: two registers, one ALU and one abstract control test unit)

(b) Show step by step implementation of $7 \div 2$ and Booth's multiplication of 3×-2 on the above hardware.

(c) In microprogrammed control unit design of MIPS given in Assignment, explain briefly the role of the following elements:

- Dispatch ROM1 and Dispatch ROM2
- 2 bit Address Control field in microinstruction
- The 4×1 multiplexor.

5. **MIPS and Cache Performance**

(a) Consider the following Array code in C:

```
void shift(int a[], int n){
int i;
for(i=0;i!=n-1;i++)
a[i]=a[i+1];
}
```

(i) Translate this function into MIPS assembly. (ii) Convert this function into pointer-based code (in C). (iii) Translate your pointer-based C code from (ii) into MIPS assembly. (iv) Compare the number of temporary registers (t-registers) needed for your array-based code from (i) and for your pointer-based code from (ii).

(b) Assume for a given machine and program: instruction cache miss rate is 2%, data cache miss rate is 4%, miss penalty is always 40 cycles, CPI of 2 without memory stalls and frequency of load/stores is 36% of instructions.(i) How much faster is a machine with a perfect cache that never misses? (ii) What happens if we speed up the machine by reducing its CPI to 1 without changing the clock rate? (iii)What happens if we speed up the machine by doubling its clock rate, but if the absolute time for a miss penalty remains same?