

DEPARTMENT

OF

COMPUTER

SCIENCE

AND ENGINEERING

**Laboratory**

**Manual**

**REGULATION**

**2023**

CS23231

–

DATA STRUCTURES

**RAJALAKSHMI ENGINEERING COLLEGE**

**An Autonomous Institution, Affiliated to Anna University Rajalakshmi Nagar, Thandalam – 602 105**



# DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

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| **CS23231 – DATA STRUCTURES**  **(*Regulation 2023*)** |
| **LAB MANUAL** |

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**LESSON PLAN**

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| **Course Code** | **Course Title**  **(Laboratory Integrated Theory Course)** | **L** | **T** | **P** | **C** |
| **CS23231** | **Data Structures** | **1** | **0** | **6** | **4** |

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|  | **LIST OF EXPERIMENTS** |
| **Sl. No** | **Name of the experiment** |
| Week 1 | Implementation of Single Linked List (Insertion, Deletion and Display) |
| Week 2 | Implementation of Doubly Linked List (Insertion, Deletion and Display) |
| Week 3 | Applications of Singly Linked List (Polynomial Manipulation) |
| Week 4 | Implementation of Stack using Array and Linked List implementation |
| Week 5 | Applications of Stack (Infix to Postfix) |
| Week 6 | Applications of Stack (Evaluating Arithmetic Expression) |
| Week 7 | Implementation of Queue using Array and Linked List implementation |
| Week 8 | Implementation of Binary Search Tree |
| Week 9 | Performing Tree Traversal Techniques |
| Week 10 | Implementation of AVL Tree |
| Week 11 | Performing Topological Sorting |
| Week 12 | Implementation of BFS, DFS |
| Week 13 | Implementation of Prim’s Algorithm |
| Week 14 | Implementation of Dijkstra’s Algorithm |
| Week 15 | Program to perform Sorting |
| Week 16 | Implementation of Open Addressing (Linear Probing and Quadratic Probing) |
| Week 17 | Implementation of Rehashing |

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**Note: Students have to write the Algorithms at left side of each problem statements.**

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| **Ex. No.: 1** | **Implementation of Single Linked List** | **Date:** |

**Write a C program to implement the following operations on Singly Linked List.**

1. **Insert a node in the beginning of a list.**
2. **Insert a node after P**
3. **Insert a node at the end of a list**
4. **Find an element in a list**
5. **FindNext**
6. **FindPrevious**
7. **isLast**
8. **isEmpty**
9. **Delete a node in the beginning of a list.**
10. **Delete a node after P**
11. **Delete a node at the end of a list**
12. **Delete the List**

**Aim:**

To implement Insert, Delete and Find Operations on a Singly Linked List.

**Algorithm:**

**Insert at Beginning:**

* Create a new node.
* Set new node's next to the current head.
* Update head to the new node.

**Insert at End:**

* Create a new node.
* If the list is empty, set head to the new node.
* Else, traverse to the last node and set its next to the new node.

**Insert in Middle:**

* Traverse to the node before the desired position.
* Create a new node.
* Set new node's next to the next node.
* Update previous node's next to the new node.

**Delete First Node:**

* If list is not empty, update head to the next node.

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| **Delete Last Node:**   * Traverse to the second last node. * Set its next to null. **Delete Node at Position:** * If position is first, delete the first node. * Else, traverse to the node before the desired position. * Update previous node's next to skip the node to be deleted.   **Search Node:**   * Traverse through the list to find the node with the given data. * Return the position or indicate if not found.   **Check if List is Empty:**   * Return true if head is null, otherwise false.   **Check if Node is Last:**   * Traverse to the node at the given position. * Check if its next is null.   **Display List:**   * Traverse through the list. * Print each node's data. | 6 |
| **Program:**    #include <stdio.h>  #include <stdlib.h>    struct node  {  int data; struct node \*link;  } \*first = NULL;    void insert\_beg(int); void insert\_end(int); void insert\_mid(int, int); void del\_first(); void del\_last(); void del\_anypos(int); void display(); void del\_all(); void isLast(int); void isEmpty(); void findnext(int); void findprev(int); int count(); void search(int);    void insert\_beg(int roll)  {  struct node \*newnode;  newnode = (struct node \*)malloc(sizeof(struct node)); newnode->data = roll; if (first == NULL)  {  newnode->link = NULL; first = newnode;  } | 7 |

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| else  {  newnode->link = first; first = newnode;  }  printf("Data inserted\n");  }    void insert\_end(int roll)  {  struct node \*newnode, \*temp; temp = first;  newnode = (struct node \*)malloc(sizeof(struct node)); newnode->data = roll; if (first == NULL)  {  newnode->link = NULL; first = newnode;  } else  {  while (temp->link != NULL)  {  temp = temp->link;  }  newnode->link = NULL; temp->link = newnode;  }  printf("Data Inserted\n");  } | 8 |

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| void display()  {  struct node \*temp = first; if (temp != NULL)  {  while (temp != NULL)  {  printf("%d ", temp->data); temp = temp->link;  }  } else  {  printf("\nNo data inside");  }  }    void insert\_mid(int loc, int roll)  {  struct node \*newnode, \*temp = NULL; temp = first; int i = 1;  newnode = (struct node \*)malloc(sizeof(struct node)); newnode->data = roll; int t = count(); if (loc == 0) insert\_beg(roll); else if (loc < t)  {  while (i < loc)  {  temp = temp->link;  i++;  } | 9 |

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| newnode->link = temp->link; temp->link = newnode; printf("Data Inserted\n");  }  else if (loc == t)  {  insert\_end(roll);  }  else if (loc > t + 1)  {  printf("Out of bounds");  }  }    int count()  {  struct node \*temp = first; int count = 0; while (temp != NULL)  {  temp = temp->link; count++;  }  return count;  }    void del\_first()  {  struct node \*temp = NULL; temp = first; if (first == NULL)  {  printf("INVALID OPERATION");  } | 10 |

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| else  {  first = temp->link; free(temp);  }  printf("Data deleted\n");  }    void del\_last()  {  struct node \*temp = NULL, \*temp1 = NULL; temp = first;  while (temp->link != NULL)  {  temp1 = temp; temp = temp->link;  }  free(temp); temp1->link = NULL; printf("Data Deleted\n");  }    void del\_anypos(int pos)  {  struct node \*temp = NULL, \*temp1 = NULL; temp = first; if (pos == 0)  {  del\_first();  } | 11 |

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| else  {  for (int i = 1; i <= pos; i++)  {  if (temp == NULL)  {  printf("INVALID"); break;  } else  {  temp1 = temp; temp = temp->link;  }  }  if (temp->link != NULL)  temp1->link = temp->link->link; else  temp1->link = temp->link; free(temp);  }  printf("Data Deleted\n");  }    void del\_all()  {  struct node \*temp = first, \*temp1 = NULL; while (temp != NULL)  {  temp1 = temp; | 12 |

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| temp = temp->link; free(temp1); first = NULL;  }  printf("\nAll data deleted successfully");  }    void isEmpty()  {  if (first == NULL)  printf("\nThe list is empty\n"); else  printf("\nThe list is not empty\n"); }    void isLast(int pos)  {  struct node \*temp = first; int i = 1; while (i < pos)  {  temp = temp->link;  i++;  }  if (temp->link == NULL) printf("\nIt is the last node"); else  printf("\nIt is not the last node");  } | 13 |

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| void search(int data)  {  int c = 1;  struct node \*temp = first; if (first == NULL)  printf("\nThe list is empty\n"); else  {  while (temp != NULL && temp->data != data)  {  temp = temp->link;  c++;  if (c > count())  printf("No data in list\n"); else  continue;  }  printf("\n%d is the position of data\n", c);  }  }    void findnext(int data)  {  int c = 1;  struct node \*temp = first; if (first == NULL)  {  printf("\nThe list is empty\n");  } | 14 |

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| else  {  while (temp != NULL && temp->data != data)  {  temp = temp->link;  c++;  if (c > count())  printf("No data in list\n"); else  continue;  }  printf("\n%d is the position of data\n", c + 1);  }  }    void findprev(int data)  {  int c = 1;  struct node \*temp = first;  if (first == NULL) printf("\nThe list is empty\n"); else  {  while (temp != NULL && temp->data != data)  {  temp = temp->link;  c++;  if (c > count())  printf("No data in list\n"); else  continue;  }  printf("\n%d is the position of data\n", c - 1);  }  } | 15 |

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| int main()  {  int n, ch, pos;  printf("MENU DRIVEN PROGRAM:\n");  printf("0. Exit\n");  printf("1. Insert a node at the beginning\n"); printf("2. Insert a node at the end\n"); printf("3. Insert a node after P\n"); printf("4. Search an element\n"); printf("5. Find next\n"); printf("6. Find previous\n"); printf("7. isLast\n"); printf("8. isEmpty\n"); printf("9. Delete at beg\n"); printf("10. Delete after P\n"); printf("11. Delete at end\n"); printf("12. Delete list\n"); printf("13. Display\n");    while (1)  {  printf("\nEnter your choice: "); scanf("%d", &ch); switch (ch)  { case 1:  printf("\nEnter roll to insert at beginning: "); scanf("%d", &n); insert\_beg(n); break; | 16 |

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| case 2:  printf("\nEnter roll to insert at end: "); scanf("%d", &n); insert\_end(n); break;    case 3:  printf("Enter P: "); scanf("%d", &pos);  printf("\nEnter roll to insert after P: "); scanf("%d", &n); insert\_mid(pos, n); break;    case 4:  printf("\nEnter data to search: "); scanf("%d", &n); search(n); break;    case 5:  printf("\nEnter data to find next: "); scanf("%d", &n); findnext(n); break;    case 6:  printf("\nEnter data to find previous: "); scanf("%d", &n); findprev(n); break; | 17 |

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| case 7:  printf("\nEnter position to check last: "); scanf("%d", &pos); isLast(pos); break;    case 8: isEmpty(); break;    case 9: del\_first(); break;    case 10:  printf("\nEnter position to delete after P: "); scanf("%d", &pos); del\_anypos(pos); break;    case 11: del\_last(); break;    case 12: del\_all(); break;    case 13: display(); break; | 18 |

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| default:  printf("\nMENU EXITED"); break;  }  if (ch == 0)  {  break;  } else  {  continue;  }  }  return 0;  } | 19 |

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| **Output:**    MENU DRIVEN PROGRAM:     1. Exit 2. Insert a node at the beginning 3. Insert a node at the end 4. Insert a node after P 5. Search an element 6. Find next 7. Find previous 8. isLast 9. isEmpty 10. Delete at beg 11. Delete after P 12. Delete at end 13. Delete list 14. Display     Enter your choice : 1    Enter roll to insert at beginning : 2  Data inserted    Enter your choice : 1    Enter roll to insert at beginning : 4  Data inserted    Enter your choice : 1    Enter roll to insert at beginning : 5  Data inserted    Enter your choice : 1    Enter roll to insert at beginning : 6  Data inserted    Enter your choice : 13  6 5 4 2  Enter your choice : 7    Enter position to check last : 2  It is not the last node | 20 |

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| Enter your choice : 4  Enter data to search : 5  2 is the position of data    Enter your choice : 0    MENU EXITED                                                                **Result:**  This code is verified and implemented successfully. | 21 |

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| 22       |  |  |  | | --- | --- | --- | | **Ex. No.: 2** | **Implementation of Doubly Linked List** | **Date:** |     **Write a C program to implement the following operations on Doubly Linked List.**   1. **Insertion** 2. **Deletion** 3. **Search** 4. **Display**       **Aim:**  To implement Insert, Delete and Find Operations on a Singly Linked List.      **Algorithm:**     * Define a struct node with integer data and pointers to the next and previous nodes. * Initialize a global pointer head to NULL. * For insertion at the beginning: * Allocate memory for a new node. * Set its data and pointers accordingly. * Update head if list is not empty, else set head to the new node. * For insertion at the end: * Allocate memory for a new node. * Traverse the list to the last node. * Update pointers to include the new node. * For insertion after a given node prev\_node: * Allocate memory for a new node. * Update pointers of the new node and its neighbors. * For deletion from the beginning: * If the list is empty, return. * Update head to point to the next node and free the old head. * For deletion from the end: * If the list is empty or has only one node, delete that node and set head to NULL. * Traverse to the second last node, update pointers, and free the last node. |

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| * For deletion after a given node prev\_node: * If prev\_node is NULL or the next node is NULL, return. * Update pointers to skip the node to be deleted and free it. * For display: * Start from head and print each node's data while traversing. * Repeat steps 3-9 based on user input until exit. | 23 |

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| **Program:**    #include <stdio.h>  #include <stdlib.h>    struct node { int data;  struct node \*next; struct node \*prev;  };    struct node \*l=NULL; struct node \*newnode;    void insert\_first(){  newnode=(struct node\*)malloc(sizeof(struct node)); if(newnode!=NULL){  printf("Enter the element : "); scanf("%d",&newnode->data); if (l!=NULL){ newnode->next=l; newnode->prev=NULL; l->prev=newnode; l=newnode;  } else  {  newnode->next=NULL; newnode->prev=NULL; l=newnode;  }  }  } | 24 |

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| void insert\_last(){  newnode=(struct node\*)malloc(sizeof(struct node)); struct node\*p; if(newnode!=NULL){ printf("enter no");  scanf("%d",&newnode->data); newnode->next=NULL; if (l!=NULL){  p=l;  while(p->next!=NULL){ p=p->next;  }  newnode->prev=p; p->next=newnode;  } else  {  newnode->prev=NULL; l=newnode;  }  }  }    void insert\_afterp(){  newnode=(struct node\*)malloc(sizeof(struct node)); struct node \*p=l; int pos,c=1; if(newnode!=NULL){  printf("Enter the element : "); scanf("%d",&newnode->data); printf("enter the positon"); scanf("%d",&pos); | 25 |

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| while(c<pos-1){ p=p->next; c++;  }  newnode->next=p->next; newnode->prev=p; p->next=newnode; p->next->prev=newnode;  }  }    void delete\_first(){ struct node\*p=l; l=l->next; l->prev=NULL; free(p);  }    void delete\_last(){ struct node\*p=l; struct node\*temp;  while(p->next->next!=NULL){ p=p->next;  }  temp=p->next; p->next=NULL; free(temp);  }    void delete\_afterp(){ struct node\*p=l; struct node \*temp; int pos,c=1;  printf("Enter position : "); | 26 |

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| scanf("%d",&pos); while(c<pos){ p=p->next; c++;  }  temp=p->next; if (temp->next==NULL){ free(temp); p->next=NULL;  }  else{  p->next=temp->next; temp->next->prev=p; free(temp);  }  }    void find(){ struct node \*p=l; int pos,c=1;  printf("enter position "); scanf("%d",&pos); while(c<pos){ p=p->next; c++;  }  printf("The element present at the position %d is %d",pos,p->data);  }    void find\_next(){ struct node \*p=l; int pos,c=1;  printf("Enter the position : "); scanf("%d",&pos); | 27 |

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| while(c<pos){ p=p->next; c++;  }  printf("The element present next to the position %d is %d",pos,p->next->data);  }    void find\_previous(){ struct node \*p=l; int pos,c=1;  printf("enter position "); scanf("%d",&pos); while(c<pos){ p=p->next; c++;  }  printf("The element present previous to the position %d is %d",pos,p->prev->data);  }      void display(){ if (l!=NULL){ struct node\*p; p=l;  while(p!=NULL){ printf("%d",p->data); p=p->next;  } } else  printf("List is empty");  } | 28 |

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| void main()  { int n;  struct node \*l=NULL;  printf("options\n1.enter at first\n2.enter at last\n3.insert after p\n4.delete first element\n5.delete last\n6.delete after p\n7.find\n8.find next\n9.find previous\n10.display\n11.exit\n"); do  {  printf("\nEnter your option:"); scanf("%d",&n); switch(n){ case 1: insert\_first(); break; case 2: insert\_last(); break; case 3: insert\_afterp(); break; case 4: delete\_first(); break; case 5: delete\_last(); break; case 6: delete\_afterp(); break; case 7: find(); break; | 29 |

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| case 8: find\_next(); break; case 9: find\_previous(); break; case 10: display(); break;  }  } while(n!=11);  } |  | 30 |

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| **Output:**    Options  1.enter at first  2.enter at last  3.insert after p  4.delete first element  5.delete last  6.delete after p  7.find  8.find next  9.find previous  10.display  11.exit    Enter your option:1  Enter the element : 1    Enter your option:1  Enter the element : 2    Enter your option:2 enter no 3    Enter your option:2 enter no 4    Enter your option:10  2 1 3 4    Enter your option:7 enter position 1  The element present at the position 1 is 2    Enter your option:5    Enter your option:10  2 1 3    Enter your option:11              **Result:**  This code is verified and implemented successfully. | 31 |

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| 32           |  |  |  | | --- | --- | --- | | **Ex. No.: 3** | **Polynomial Manipulation** | **Date:** |     **Write a C program to implement the following operations on Singly Linked List.**   1. **Polynomial Addition** 2. **Polynomial Subtraction** 3. **Polynomial Multiplication**             **Aim:**    To write a C program to implement the following operations on singly linked list   1. Polynomial Addition 2. Polynomial Subtraction 3. Polynomial Multiplication     **Algorithm:**     1. Start 2. Define structure 3. Create term functions 4. Insert term into the polynomial and add subtract and multiplication these polynomial and display it. 5. End |

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| **Program:**    #include<stdio.h>  #include<stdlib.h>    struct node{  int coeff; int pow;  struct node \*next;  };    struct node\* create\_node()  {  struct node \*p;  p=(struct node\*)malloc(sizeof(struct node)); if(p!=NULL)  {  printf("Enter the coefficient:-"); scanf("%d",&p->coeff); printf("Enter the power of x:-"); scanf("%d",&p->pow); p->next=NULL;  }  return p;  }    struct node\* create\_list(int n)  {  struct node \*temp, \*L1,\*new;  L1 = (struct node\*)malloc(sizeof(struct node)); temp =L1; while(n--)  {  new = create\_node(); new->next = NULL; | 33 |

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| temp->next = new; temp = new;  }  temp->next=NULL; return L1;  }    void display(struct node \*L)  {  struct node \*p; p= L->next; while(p!=NULL)  {  printf("%dx^",p->coeff); printf("%d",p->pow); if(p->next!=NULL)  {  printf("+");  }  p = p->next;  }  printf("\n");  }    struct node\* addition(struct node \*L1,struct node \*L2)  {  struct node \*p1,\*p2,\*new, \*L3,\*temp;    L3 = (struct node\*)malloc(sizeof(struct node)); L3->next=NULL; temp = L3; p1=L1->next; p2 = L2->next; | 34 |

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| while(p1!=NULL && p2!=NULL )  {  if(p1->pow == p2->pow)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p1->coeff+p2->coeff; new->pow = p1->pow; p1 = p1->next; p2 = p2->next;  }  else if(p1->pow > p2->pow)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p1->coeff; new->pow = p1->pow; p1 = p1->next;  }  else if(p1->pow < p2->pow)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p2->coeff; new->pow = p2->pow; p2 = p2->next;  }  temp->next = new; new->next= NULL; temp = temp->next;  }    if(p1==NULL)  {  while(p2!=NULL)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p2->coeff; | 35 |

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| new->pow = p2->pow; temp->next = new; new->next= NULL; temp = temp->next; p2 = p2->next;  }  }  else if(p2==NULL)  {  while(p1!=NULL)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p1->coeff; new->pow = p1->pow; temp->next = new; new->next= NULL; temp = temp->next; p1 = p1->next;  }  }  return L3;  }    struct node\* subtraction(struct node \*L1,struct node \*L2)  {  struct node \*p1,\*p2,\*new, \*L3,\*temp;    L3 = (struct node\*)malloc(sizeof(struct node)); L3->next=NULL; temp = L3; p1=L1->next; p2 = L2->next; | 36 |

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| while(p1!=NULL && p2!=NULL )  {  if(p1->pow == p2->pow)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p1->coeff - p2->coeff; new->pow = p1->pow; p1 = p1->next; p2 = p2->next;  }  else if(p1->pow > p2->pow)  { new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p1->coeff; new->pow = p1->pow; p1 = p1->next;  }  else if(p1->pow < p2->pow)  { new = (struct node\*)malloc(sizeof(struct node)); new->coeff = -p2->coeff; new->pow = p2->pow; p2 = p2->next;  }  temp->next = new; new->next= NULL; temp = temp->next;  }    if(p1==NULL)  {  while(p2!=NULL)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p2->coeff; new->pow = p2->pow; | 37 |

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| temp->next = new; new->next= NULL; temp = temp->next; p2 = p2->next;  }  }  else if(p2==NULL)  {  while(p1!=NULL)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p1->coeff; new->pow = p1->pow; temp->next = new; new->next= NULL; temp = temp->next; p1 = p1->next;  }  }  return L3;  }    struct node\* multiplication(struct node \*L1,struct node \*L2)  {  struct node \*p1,\*p2,\*new, \*L3,\*temp;    L3 = (struct node\*)malloc(sizeof(struct node)); L3->next=NULL; temp = L3; p1=L1->next; p2 = L2->next; while(p1!=NULL)  {  p2 = L2->next; | 38 |

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| while(p2!=NULL)  {  new = (struct node\*)malloc(sizeof(struct node)); new->coeff = p2->coeff\*p1->coeff; new->pow = p1->pow+p2->pow; temp->next = new; new->next= NULL; temp = temp->next; p2 =p2->next;  }  p1 = p1->next;  }  return L3;  }    struct node\* add(struct node \*l3)  {  struct node \*temp,\*p,\*ref; temp = l3->next; while(temp!=NULL)  {  p = temp->next; ref =temp; while(p!=NULL)  {  if(temp->pow==p->pow)  {  temp->coeff = temp->coeff + p->coeff; ref->next = p->next; free(p); p=ref->next;  } | 39 |

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| else  {  ref=ref->next; p=p->next;  }  }  temp = temp->next;  }  return l3;  }    int main()  {  struct node \*l1 , \*l2,\*la,\*ls,\*lm; int n;    printf("Enter the polynomials in Descending order only"); printf("\nNO. of terms in polynomial 1:-"); scanf("%d",&n); l1 = create\_list(n);    printf("\nNO. of terms in polynomial 2:-"); scanf("%d",&n); l2 = create\_list(n);    printf("L1="); display(l1); printf("L2="); display(l2);    printf("\nThe Sum of the two polynomial is="); la=addition(l1,l2); display(la); | 40 |

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| printf("The difference of the two polynomial is="); ls=subtraction(l1,l2); display(ls);    printf("The product of the two polynomial is="); lm=multiplication(l1,l2); lm=add(lm); display(lm);  } | 41 |

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| **Output:**    Enter the polynomials in Descending order only  NO. of terms in polynomial 1: 3  Enter the coefficient:- 2  Enter the power of x:- 3  Enter the coefficient:- 3  Enter the power of x:- 2  Enter the coefficient:- 4  Enter the power of x:- 1    NO. of terms in polynomial 2: 4  Enter the coefficient:- 1  Enter the power of x:- 4  Enter the coefficient:- 2  Enter the power of x:- 3  Enter the coefficient:- 5  Enter the power of x:- 2  Enter the coefficient:- 1  Enter the power of x:- 1    L1=2x^3+3x^2+4x^1  L2=1x^4+2x^3+5x^2+1x^1    The Sum of the two polynomial is=1x^4+4x^3+8x^2+5x^1  The difference of the two polynomial is=-1x^4+0x^3+-2x^2+3x^1  The product of the two polynomial is=2x^7+7x^6+20x^5+25x^4+23x^3+4x^2                      **Result:** This code is verified and implemented successfully. | 42 |

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| 43       |  |  |  | | --- | --- | --- | | **Ex. No.: 4** | **Implementation of Stack using Array and Linked List Implementation** | **Date:** |     **Write a C program to implement a stack using Array and linked List implementation and execute the following operation on stack.**   1. **Push an element into a stack** 2. **Pop an element from a stack** 3. **Return the Top most element from a stack** 4. **Display the elements in a stack**     **Aim:**    To write a c program to implement a stack using array and linked list implementation and execute the following operation on stack.    (i)Push an element into a stack     * 1. Pop an element from a stack      * 1. Return the Top most element from a stack      * 1. Display the elements in a stack       **Algorithm:**     1. Start      1. Create a structure and functions for the given operations.      1. Initialize Stack array with capacity and top=1.      1. To push an element into a stack read Itu data to be pushed. If the top is equal to capacity-1 display stack over flow otherwise increment the top and push the data onto Stack at index top.      1. To pop an element from a Stack if the is equal to-I display as stack underflow. Alter wise pop delta from Stack at index fop the decrement the top and display the popped data.      1. To return the pop most element from a Stack it the top is equal to-1 display Stack is empty. Otherwise display all elements in stack from top too.      1. After these operations display all elements in Stack from top too.      1. End. |

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| **STACK USING ARRAY Program:**    #include <stdio.h>  #define size 100    int stack[size]; int top = -1, i;    void push() {  int a;  printf("Enter the data to insert in stack : "); scanf("%d", &a); if (top == size - 1) { printf("Stack is full\n");  } else {  top = top + 1; stack[top] = a;  }  }    void pop() {  int a;  if (top == -1) {  printf("The stack is empty\n");  } else {  a = stack[top];  printf("Item popped is : %d\n", a); top--;  }  } | 44 |

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| void peek() { if (top == -1) {  printf("The stack is empty\n");  } else {  printf("The top most element in the stack is : %d\n", stack[top]);  }  }    void display() { if (top == -1) {  printf("Stack is empty\n");  } else {  printf("Items in the stack are : "); for (i = top; i >= 0; i--) printf("%d ", stack[i]); printf("\n");  }  }    int main() { int choice;  printf("STACK IMPLEMENTATION USING ARRAY\n"); printf("1.Push\n2.Pop\n3.Peek\n4.Display\n5.Exit\n"); do {  printf("Enter Your Choice : "); scanf("%d", &choice); switch (choice) { case 1: push(); break; case 2: pop(); break; | 45 |

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| case 3:  peek(); break; case 4: display(); break; case 5: printf("Exiting!!\n"); break; default:  printf("Invalid choice\n");  }  } while (choice != 5); return 0;  } | 46 |

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| **Output:**  Operations:  1.Push  2.Pop  3.Peek  4.Display  5.Exit    Enter Your Choice : 1  Enter the data to insert in stack : 25    Enter Your Choice : 1  Enter the data to insert in stack : 45    Enter Your Choice : 1  Enter the data to insert in stack : 53    Enter Your Choice : 1  Enter the data to insert in stack : 24    Enter Your Choice : 4  Items in the stack are : 24 53 45 25    Enter Your Choice : 2  Item popped is : 24    Enter Your Choice : 3  The top most element in the stack is : 53  \  Enter Your Choice : 4  Items in the stack are : 53 45 25    Enter Your Choice : 5 Exiting!! | 47 |

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| **STACK USING LINKED LIST:**    **Program:**    #include <stdio.h>  #include <stdlib.h>    struct Node { int data;  struct Node\* next;  };    struct Node\* top = NULL;    void push(int x) {  struct Node\* temp = (struct Node\*)malloc(sizeof(struct Node)); if (temp == NULL) {  printf("Stack Overflow\n"); return;  }  temp->data = x; temp->next = top; top = temp;  }    void pop() { if (top == NULL) {  printf("Stack Underflow\n"); return;  }  struct Node\* temp = top; top = top->next; free(temp);  } | 48 |

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| int peek() { if (top == NULL) {  printf("Stack is empty\n"); return -1;  }  return top->data;  }    void display() {  struct Node\* temp = top; printf("Stack: "); while (temp != NULL) { printf("%d ", temp->data); temp = temp->next;  }  printf("\n");  }    int main() { int choice, item;  printf("STACK IMPLEMENTATION USING LINKED LIST\n"); printf("1. Push\n2. Pop\n3. Peek\n4. Display\n5. Exit\n"); do {  printf("Enter your choice: "); scanf("%d", &choice); switch (choice) { case 1:  printf("Enter element to push: "); scanf("%d", &item); push(item); break; case 2: pop(); break; case 3:  printf("Top element: %d\n", peek()); break; | 49 |

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| case 4: display(); break; case 5: printf("Exiting...\n"); break; default:  printf("Invalid choice\n");  }  } while (choice != 5); return 0;  } | 50 |

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| **Output:**  Operations:   1. Push 2. Pop 3. Peek 4. Display 5. Exit     Enter your choice: 1  Enter element to push: 43    Enter your choice: 1  Enter element to push: 32    Enter your choice: 4  Stack: 32 43    Enter your choice: 1  Enter element to push: 124    Enter your choice: 4  Stack: 124 32 43    Enter your choice: 2    Enter your choice: 3  Top element: 32    Enter your choice: 5 Exiting...    **Result:**  This code is verified and implemented successfully | 51 |

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| 52     |  |  |  | | --- | --- | --- | | **Ex. No.: 5** | **Infix to Postfix Conversion** | **Date:** |     **Write a C program to perform infix to postfix conversion using stack.**    **Aim:**  To perform infix to postfix conversion using stack.    **Algorithm:**     1. Start      1. Define a structure for the Node with character data and a pointer to the next node.      1. Define a function to determine the priority of operators.      1. Define a function to push a symbol onto the stack.      1. Define a function to pop a symbol from the stack. - Check if the stack is empty. If so, print "Stack Underflow" and exit.      1. Define a function to peek at the top symbol in the stack. - If the stack is empty, return null character '\0'.      1. Define a function to display the stack. - If the stack is empty, print "The stack is empty".      1. Define a function to check the precedence and process operators accordingly.      1. In the main function:    1. Define variables for input string, symbol, and a stack. - Initialize the stack as NULL.    2. Prompt the user to enter an expression. - Read the expression from the user.    3. Iterate through each character in the expression:       1. If it's an alphabet character, print it       2. If it's an operator, call the check\_precedence function.       3. If it's a space, continue to the next character. iv. If it's an opening parenthesis '(', push it onto the stack.       4. If it's a closing parenthesis ')', pop and print symbols from the stack until an opening parenthesis is encountered.       5. If it's any other character, print "Invalid expression" and break the loop.    4. After the loop, pop and print any remaining symbols from the stack.      1. End. |

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| **Program:**    #include <stdio.h>  #include <stdlib.h>    struct Node  { char sign; struct Node\* next;  };    int priority(char sym)  { if(sym=='\*'||sym=='/'||sym=='%') return 2; else if(sym=='+'||sym=='-') return 1; else return 0;  }    void push(struct Node\* L,char sym)  { struct Node\*n = (struct Node\*) malloc(sizeof(struct Node)); if(n!=NULL)  {  n->sign=sym; if(L->next!=NULL)  {  n->next=L->next;  L->next=n;  } | 53 |

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| else  L->next=n;  }  }    void pop(struct Node\* L)  { if(L->next==NULL) printf("\n---Stack Underflow---\n"); else  {  struct Node\* temp=L->next; L->next = L->next->next; free(temp);  }  }    char peek(struct Node\* L)  {  if(L->next==NULL) return '\0'; else return L->next->sign;  }    void display(struct Node\* L)  {  if(L->next==NULL)  printf("\nThe stack is empty\n"); else  {  struct Node\* temp=L->next; | 54 |

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| while(temp!=NULL)  {  printf(" | %c |\n",temp->sign); temp=temp->next;  }  }  }    void check\_precedence(struct Node\*L,char in\_exp)  { char in\_stack=peek(L);    if(priority(in\_stack) >= priority(in\_exp))  { printf("%c",in\_stack); pop(L); check\_precedence(L,in\_exp);  }    else  {  push(L,in\_exp);  }  }    int main() { char str[100],sym; struct Node list; list.next=NULL; printf("Enter expression containing lowercase alphabets and operators (+,-,\*,/,%)\n"); scanf("%[^\n]s",str); | 55 |

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| for(int i=0;str[i]!='\0';i++)  {  if((str[i]>='a'&& str[i]<='z')||(str[i]>='A' && str[i]<='Z'))  { printf("%c",str[i]);  }    else if(str[i]=='+'||str[i]=='-'||str[i]=='\*'||str[i]=='/')  {  check\_precedence(&list,str[i]);  }  else if(str[i]==' ') continue;    else if(str[i]=='(') push(&list,str[i]);    else if(str[i]==')')  { while(peek(&list)!='(')  {  printf("%c",peek(&list)); pop(&list);  }  pop(&list);  } else  {  printf("Invalid expression "); break;  }  } | 56 |

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| while(list.next)  {  printf("%c",peek(&list)); pop(&list);  } return 0;  }                  **Output:**    Enter expression containing lowercase alphabets and operators (+,-,\*,/,%) a+b\*c/d-e  abc\*d/+e-                  **Result:**  Hence the code is implemented and executed successfully. | 57 |

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| 58     |  |  |  | | --- | --- | --- | | **Ex. No.: 6** | **Evaluating Arithmetic Expression** | **Date:** |     **Write a C program to evaluate Arithmetic expression using stack.**    **Aim:**  To evaluate arithmetic expression using stack    **Algorithm:**    1.Start    2.Define an array stack to hold operands, and a character array str to store the input expression.    3.Define a function push to push an operand onto the stack.    4.Define a function pop to pop an operand from the stack.    5.Define a function evaluate to perform arithmetic operations on two operands.    6.In the main function:   * Declare variables temp and i. * Prompt the user to enter an equation. * Read the equation into the str array. * Iterate through each character in str: * If the character is a digit, update temp by multiplying its current value by 10 and adding the digit. * If the character is a space, push the accumulated number temp onto the stack and reset temp to 0. * If the character is an operator ('+', '-', '\*', '/', '%'): * Pop two operands (num2 and num1) from the stack. * Evaluate the expression (num1 op num2) using the operator and push the result onto the stack. * Increment i to skip the next character (since it's an operator). * Check if the last character in the expression is a digit or if there's only one element left in the stack. If not, print "Invalid expression" and exit. * Print the final result, which is the only element left in the stack.   •  7.End. |

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| **Program:**    #include<stdio.h>  #include<stdlib.h>    int stack[30]; char str[30]; int top=-1;    void push(int num)  { top++; stack[top]=num;  }    int pop()  { int last=stack[top]; top--; if(top!=-2) return last; else {  printf("Invalid expression..."); exit(-1);  }  }    int evaluate(int num1,int num2,char op)  { switch(op)  { case '+':  return num1+num2; break; | 59 |

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| case '-':  return num1-num2; break;  case '\*':  return num1\*num2; break;  case '/':  return num1/num2; break;    case '%':  return num1%num2;  break;  }  }    void main()  { int temp=0,i;  printf("Enter equation: "); scanf("%[^\n]s",str); for(i=0;str[i]!='\0';i++)  { if(str[i]>='0'&& str[i]<='9') temp=temp\*10+((int)(str[i]-'0'));  else if(str[i]==' ')  { push(temp); temp=0;  } | 60 |

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| else if(str[i]=='+'||str[i]=='-'||str[i]=='\*'||str[i]=='/'||str[i]=='%')  {  int num2=pop(); int num1=pop(); int result=evaluate(num1,num2,str[i]); push(result); i++;  }  }    if(str[i-1]>='0'&& str[i+1]<='9' || top!=0)  { printf("Invalid expression..."); exit(-1);  }    printf("Result = %d",pop());  }              **Output:**    Enter equation: 5 3 \* 8 - Result = 7          **Result:**  Hence the code is implemented and executed successfully. | 61 |

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| 62     |  |  |  | | --- | --- | --- | | **Ex. No.: 7** | **Implementation of Queue using Array and Linked List Implementation** | **Date:** |     **Write a C program to implement a Queue using Array and linked List implementation and execute the following operation on stack.**   1. **Enqueue** 2. **Dequeue** 3. **Display the elements in a Queue**     **Aim:** To implement queue using array and linked list and perform basic operations of queue.    **Algorithm:**    **1. Linked List implementation**     * Define a structure for node which contains two parts: data and a pointer to the next node.      * Create a new node and put the data in the data part of new node. New node should be added to the end of previous node.      * To remove an element, first check if the queue is empty or not, if it is not empty, remove the first element and move the pointer pointing to the first node to the next node.     **2. Array Implementation**    \*Create an array of any size and new variables: front and rear with initial value -1.     * To insert the data, first check if rear is equal to max size of array or not. If not equal, increment rear and add the new value to array.      * To delete the data, first check if queue is empty or not. If it is not empty, print the value and increment the value of front. |

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| }Node; | **Linked List implementation:**  #include<stdio.h> #include<stdlib.h>  typedef struct node{  int data;  struct node\* next;    void enqueue(Node\*\* queue,int val){  Node\* newnode=malloc(sizeof(Node));  Node\* cur; if(newnode){  newnode->data =val; newnode->next = NULL; if(\*queue==NULL){  \*queue = newnode; cur =\*queue;  }  else{ cur->next= newnode; cur = newnode;  }  } else{  printf("\nMemory allocation failed\n"); exit(1);  } | 63 |
| }    void peek(Node\* queue){  if(queue){  printf("\nThe first element in the queue is %d",queue->data);  }  else{  printf("\nThe queue is empty");  return;  }  }    int dequeue(Node\*\* queue){ if(\*queue){  Node\* temp = \*queue; (\*queue) = (\*queue)->next;  int x = temp->data; free(temp);  return x;  } | |  |

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| else{  printf("\nQueue is empty"); return -1;  }  }      void display(Node\* queue){  if(queue){ while(queue){  printf("%d\t",queue->data);  queue = queue->next;  }  }  else{  printf("\nThe queue is empty");  return;  }  }    int main(){  Node\* queue= NULL; int n,choice;  do{  printf("\n1. ENQUEUE\n2. DEQUEUE \n3. PEEK \n4. DISPLAY \n5.EXIT"); printf("\nENTER YOUR CHOICE: ");  scanf("%d",&choice);  switch(choice){  case 1:{  printf("\nEnter the element to enqueue: ");  scanf("%d",&n);  enqueue(&queue,n);  break;  }  case 2:{ n = dequeue(&queue);  if(n!=-1){  printf("\nThe dequeued element is %d",n);  break;  }  }  case 3: peek(queue); break;  case 4: display(queue); break;  } | | 64 |
| } | }while(choice<=4);    return 0; |  |

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| **Output:**     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 1    Enter the element to enqueue: 2     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 1    Enter the element to enqueue: 4     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 1    Enter the element to enqueue: 5     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 1    Enter the element to enqueue: 6     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 2    The dequeued element is 2   1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 3 | 65 |

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| The first element in the queue is 4   1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 4  4 5 6     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 5 | 66 |

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| **Array Implementation:**    #include<stdio.h> #define MAX 10  int queue[MAX],front=-1,rear = -1;    void enqueue(int v){  if(front == MAX-1){ printf("\nQueue is full");  return;  }  queue[++rear] = v;  if(front == -1){ front++;  }  }    int dequeue(){  if(front ==-1){  printf("\nQueue is empty"); return -1;  }  int temp = queue[front]; if(front == rear){ front = -1;  rear = -1;  }  front++; return temp;  }    void peek(){  if(front ==-1){  printf("\nQueue is empty");  return;  }  printf("\nThe first element in the queue is %d",queue[front]);    }    void display(){  if(front ==-1){  printf("\nQueue is empty");  return;  }  printf("\nGiven queue is "); for (int i =front;i<=rear;i++)  printf("%d\t",queue[i]);  printf("\n");    } | 67 |

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| int main(){  int n,choice;  do{  printf("\n1. ENQUEUE\n2. DEQUEUE \n3. PEEK \n4. DISPLAY \n5.EXIT"); printf("\nENTER YOUR CHOICE: ");  scanf("%d",&choice); switch(choice){  case 1:{  printf("\nEnter the element to enqueue: ");  scanf("%d",&n); enqueue(n);  break;  }  case 2:{ n = dequeue();  if(n!=-1){  printf("\nThe dequeued element is %d",n);  break;  }  }  case 3: peek(); break;  case 4: display(); break;  }    }while(choice<=4);  } | 68 |

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| **OUTPUT:**   1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 1    Enter the element to enqueue: 2     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 1    Enter the element to enqueue: 4     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 1    Enter the element to enqueue: 6     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 4    Given queue is 2 4 6     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 2  The dequeued element is 2     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 3  The first element in the queue is 4 | 69 |

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| 70   1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 4    Given queue is 4 6     1. ENQUEUE 2. DEQUEUE 3. PEEK 4. DISPLAY   5.EXIT  ENTER YOUR CHOICE: 5                                                          **Result:**  Hence, the implementation of queue using linked list and array is done and verified. |

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| 71     |  |  |  | | --- | --- | --- | | **Ex. No.: 8** | **Tree Traversal** | **Date:** |     **Write a C program to implement a Binary tree and perform the following tree traversal operation.**   1. **Inorder Traversal** 2. **Preorder Traversal** 3. **Postorder Traversal**                     **Aim:**  Performing tree traversal techniques      **Algorithm:**     1. Start 2. Create a tree node **3. In-order**   Traverse the left subtree, visit the root node, and then traverse the right subtree.   1. **Pre-Order Traversal**   Visit the root node, traverse the left subtree, and then traverse the right subtree.   1. **Post-Order Traversal**   Traverse the left subtree, traverse the right subtree, and then visit the root node.   1. Than build a tree. 2. Int main() function perform the tree traversal techniques. 3. Stop |

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| **Program:**    #include <stdio.h>  #include <stdlib.h>    struct TreeNode {  int data;  struct TreeNode \*left; struct TreeNode \*right;  };    struct TreeNode\* createNode(int data) {  struct TreeNode\* newNode = (struct TreeNode\*)malloc(sizeof(struct TreeNode)); newNode->data = data; newNode->left = NULL; newNode->right = NULL; return newNode;  }    void inorderTraversal(struct TreeNode\* root) { if (root != NULL) {  inorderTraversal(root->left); printf("%d ", root->data); inorderTraversal(root->right);  }  }    void preorderTraversal(struct TreeNode\* root) { if (root != NULL) {  printf("%d ", root->data); preorderTraversal(root->left); preorderTraversal(root->right);  }  } | 72 |

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| void postorderTraversal(struct TreeNode\* root) { if (root != NULL) {  postorderTraversal(root->left); postorderTraversal(root->right); printf("%d ", root->data);  }  }    struct TreeNode\* buildTree() { int data;  struct TreeNode \*root = NULL;    printf("Enter data (Enter -1 to stop): "); scanf("%d", &data);    if (data == -1) return NULL; root = createNode(data);    printf("Enter left child of %d:\n", data); root->left = buildTree();    printf("Enter right child of %d:\n", data); root->right = buildTree();    return root;  }    int main() {  printf("Enter the binary tree (Enter -1 to stop):\n"); struct TreeNode\* root = buildTree();    printf("\nIn-order traversal: "); inorderTraversal(root); printf("\n"); | 73 |

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| printf("Pre-order traversal: "); preorderTraversal(root); printf("\n");    printf("Post-order traversal: "); postorderTraversal(root); printf("\n");    return 0;  } | 74 |

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| **Output:**    Enter the binary tree (Enter -1 to stop): Enter data (Enter -1 to stop): 1 Enter left child of 1:  Enter data (Enter -1 to stop): 2 Enter left child of 2:  Enter data (Enter -1 to stop): 4 Enter left child of 4:  Enter data (Enter -1 to stop): -1 Enter right child of 4:  Enter data (Enter -1 to stop): -1 Enter right child of 2:  Enter data (Enter -1 to stop): 5 Enter left child of 5:  Enter data (Enter -1 to stop): -1 Enter right child of 5:  Enter data (Enter -1 to stop): -1 Enter right child of 1:  Enter data (Enter -1 to stop): 3 Enter left child of 3:  Enter data (Enter -1 to stop): -1 Enter right child of 3:  Enter data (Enter -1 to stop): -1      In-Order Traversal: 4 2 5 1 3  Pre-Order Traversal: 1 2 4 5 3  Post-Order Traversal: 4 5 2 3 1          1  / \  2 3  / \  4 5              **Result:**  Hence, the tree traversal code is implemented and executed successfully. | 75 |

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| 76       |  |  |  | | --- | --- | --- | | **Ex. No.: 9** | **Implementation of Binary Search tree** | **Date:** |     **Write a C program to implement a Binary Search Tree and perform the following operations.**   1. **Insert** 2. **Delete** 3. **Search** 4. **Display**     **Aim:**  Implement a binary search tree to perform insertion,deletion,search and display  operation.    **Algorithm:**     1. Start: Begin. 2. Define Node Structure: Define node structure. 3. Create New Node: Function to create a new node. 4. Insert Node: Insert a new node while maintaining BST property. 5. Delete Node: Delete a node while preserving BST property. 6. Find Minimum Value: Find the minimum value in a subtree. 7. Search Node: Recursive search function. 8. Inorder Traversal: Print nodes in sorted order. 9. End: Finish. |

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| **Program:**    #include <stdio.h>  #include <stdlib.h>    struct node { int data;  struct node \*leftChild, \*rightChild;  };  struct node \*root = NULL;    struct node \*newNode(int item) {  struct node \*temp = (struct node \*)malloc(sizeof(struct node)); if (!temp) {  printf("Memory allocation failed\n"); exit(1);  }  temp->data = item;  temp->leftChild = temp->rightChild = NULL; return temp;  }    void insert(int data) {  struct node \*tempNode = newNode(data); struct node \*current; struct node \*parent; if (root == NULL) { root = tempNode; return;  }  current = root; parent = NULL; | 77 |

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| while (1) { parent = current; if (data < parent->data) { current = current->leftChild; if (current == NULL) {  parent->leftChild = tempNode; return;  } } else {  current = current->rightChild; if (current == NULL) {  parent->rightChild = tempNode; return;  }  }  }  }    struct node\* search(int data) { struct node \*current = root;  while (current != NULL && current->data != data) { if (data < current->data) { current = current->leftChild;  } else {  current = current->rightChild;  }  }  return current;  } | 78 |

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| void printTree(struct node\* Node) { if (Node == NULL) return; printTree(Node->leftChild); printf(" %d", Node->data); printTree(Node->rightChild);  }    struct node\* findMin(struct node\* node) { struct node\* current = node;  while (current && current->leftChild != NULL) current = current->leftChild; return current;  }    struct node\* deleteNode(struct node\* root, int data) { if (root == NULL) return root; if (data < root->data)  root->leftChild = deleteNode(root->leftChild, data); else if (data > root->data)  root->rightChild = deleteNode(root->rightChild, data); else {  if (root->leftChild == NULL) {  struct node \*temp = root->rightChild; free(root); return temp;  } else if (root->rightChild == NULL) { struct node \*temp = root->leftChild; free(root); return temp;  }  struct node\* temp = findMin(root->rightChild); root->data = temp->data;  root->rightChild = deleteNode(root->rightChild, temp->data);  }  return root;  } | 79 |

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| int main() { int choice, data; while (1) {  printf("\nMenu:\n"); printf("1. Insert\n"); printf("2. Search\n"); printf("3. Delete\n"); printf("4. Print In-order\n"); printf("5. Exit\n");  printf("Enter your choice: "); scanf("%d", &choice); switch (choice) { case 1:  printf("Enter data to insert: "); scanf("%d", &data); insert(data);  printf("Insertion done\n"); break; case 2:  printf("Enter data to search: "); scanf("%d", &data); struct node \*k; k = search(data); if (k != NULL)  printf("Element %d found\n", k->data); else  printf("Element not found\n"); break; case 3:  printf("Enter data to delete: "); scanf("%d", &data);  root = deleteNode(root, data); printf("Deletion done\n"); break; | 80 |

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| case 4:  printf("BST in-order:\n"); printTree(root); printf("\n"); break;    case 5:  exit(0); default:  printf("Invalid choice\n");  }  }  return 0;  } | 81 |

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| **Output:**    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 1  Enter data to insert: 2  Insertion done    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 1  Enter data to insert: 3  Insertion done    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 1  Enter data to insert: 4  Insertion done    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 1  Enter data to insert: 1  Insertion done    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 4 BST in-order:  1 2 3 4 |  | 82 |

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| Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 2  Enter data to search: 2  Element 2 found at address 0x1820ac0    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 3  Enter data to delete: 3  Deletion done    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 4 BST in-order:  1 2 4    Menu:   1. Insert 2. Search 3. Delete 4. Print In-order 5. Exit   Enter your choice: 5                    **Result:** Thus the code is implemented and executed successfully. | 83 |

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| 84     |  |  |  | | --- | --- | --- | | **Ex. No.: 10** | **Implementation of AVL Tree** | **Date:** |     **Write a function in C program to insert a new node with a given value into an AVL tree. Ensure that the tree remains balanced after insertion by performing rotations if necessary. Repeat the above operation to delete a node from AVL tree.**      **Aim:**  Design and implement functions in C to insert and delete nodes in an AVL tree,  ensuring the tree remains balanced by performing necessary rotations.    **Algorithm**:     1. Define the structure for an AVL tree node. 2. Implement a function to calculate the height of a node. 3. Implement a function to calculate the maximum of two integers. 4. Implement a function to create a new node with a given key. 5. Implement a function to perform a right rotation on a subtree. 6. Implement a function to perform a left rotation on a subtree. 7. Implement a function to get the balance factor of a node. 8. Implement a function to insert a new key into the AVL tree:    1. Recursively find the correct position for the new key.    2. Insert the node and update the height.    3. Check the balance factor and perform necessary rotations. 9. Implement a function to delete a key from the AVL tree:    1. Recursively find the node to be deleted.    2. Handle cases with one or no children.    3. Use in-order successor for nodes with two children.    4. Update heights and balance the tree by performing necessary rotations. 10. Implement a function to print the tree in pre-order traversal to display the structure. |

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| **Program:**    #include <stdio.h>  #include <stdlib.h>    struct Node {  int key;  struct Node \*left; struct Node \*right; int height;  };    int height(struct Node \*N) { if (N == NULL) return 0; return N->height;  }    int max(int a, int b) { return (a > b) ? a : b;  }    struct Node\* newNode(int key) {  struct Node\* node = (struct Node\*)malloc(sizeof(struct Node)); node->key = key; node->left = NULL; node->right = NULL; node->height = 1; return(node);  }    struct Node \*rightRotate(struct Node \*y) { struct Node \*x = y->left; struct Node \*T2 = x->right; x->right = y; y->left = T2; | 85 |

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| y->height = max(height(y->left), height(y->right)) + 1; x->height = max(height(x->left), height(x->right)) + 1; return x;  }    struct Node \*leftRotate(struct Node \*x) { struct Node \*y = x->right; struct Node \*T2 = y->left; y->left = x; x->right = T2;  x->height = max(height(x->left), height(x->right)) + 1; y->height = max(height(y->left), height(y->right)) + 1; return y;  }    int getBalance(struct Node \*N) { if (N == NULL) return 0;  return height(N->left) - height(N->right);  }    struct Node\* insert(struct Node\* node, int key) { if (node == NULL) return(newNode(key)); if (key < node->key)  node->left = insert(node->left, key); else if (key > node->key)  node->right = insert(node->right, key); else  return node;  node->height = 1 + max(height(node->left), height(node->right)); int balance = getBalance(node); if (balance > 1 && key < node->left->key) return rightRotate(node);  if (balance < -1 && key > node->right->key) return leftRotate(node); | 86 |

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| if (balance > 1 && key > node->left->key) { node->left = leftRotate(node->left); return rightRotate(node);  }  if (balance < -1 && key < node->right->key) { node->right = rightRotate(node->right); return leftRotate(node);  }  return node;  }    struct Node\* minValueNode(struct Node\* node) { struct Node\* current = node; while (current->left != NULL) current = current->left; return current;  }    struct Node\* deleteNode(struct Node\* root, int key) { if (root == NULL) return root; if (key < root->key)  root->left = deleteNode(root->left, key); else if (key > root->key)  root->right = deleteNode(root->right, key); else {  if (root->left == NULL) {  struct Node \*temp = root->right; free(root); return temp;  } else if (root->right == NULL) { struct Node \*temp = root->left; free(root); return temp;  } | 87 |

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| struct Node \*temp = minValueNode(root->right); root->key = temp->key;  root->right = deleteNode(root->right, temp->key);  }  if (root == NULL) return root;  root->height = 1 + max(height(root->left), height(root->right)); int balance = getBalance(root);  if (balance > 1 && getBalance(root->left) >= 0) return rightRotate(root);  if (balance > 1 && getBalance(root->left) < 0) { root->left = leftRotate(root->left); return rightRotate(root);  }  if (balance < -1 && getBalance(root->right) <= 0) return leftRotate(root);  if (balance < -1 && getBalance(root->right) > 0) { root->right = rightRotate(root->right); return leftRotate(root);  }  return root;  }    void preOrder(struct Node \*root) { if (root != NULL) { printf("%d ", root->key); preOrder(root->left); preOrder(root->right);  }  } | 88 |

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| int main() {  struct Node \*root = NULL; int value, c, a; while (1) {  printf("\nOperations:\n"); printf("1. Insert element\n"); printf("2. Delete element\n"); printf("3. Display tree\n"); printf("4. Exit\n");  printf("Enter your choice: "); scanf("%d", &c);    switch (c) { case 1:  printf("Enter numbers to insert into the tree (enter -1 to stop): "); while (1) {  scanf("%d", &value); if (value == -1) break;  root = insert(root, value);  } break; case 2:  printf("Enter the number to delete: "); scanf("%d", &a);  root = deleteNode(root, a); break; case 3:  printf("Pre-order traversal of the constructed AVL tree: "); preOrder(root); printf("\n"); break; case 4:  printf("Exiting...\n"); exit(0); | 89 |

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| default:  printf("Invalid choice! Please try again.\n");  }  }  return 0;  }    **Output:**    Operations:   1. Insert element 2. Delete element 3. Display tree 4. Exit   Enter your choice: 1  Enter numbers to insert into the tree (enter -1 to stop): 10 5 15 20 -1    Operations:   1. Insert element 2. Delete element 3. Display tree 4. Exit   Enter your choice: 3  Pre-order traversal of the constructed AVL tree: 10 5 15 20    Operations:   1. Insert element 2. Delete element 3. Display tree 4. Exit   Enter your choice: 2  Enter the number to delete: 5    Operations:   1. Insert element 2. Delete element 3. Display tree 4. Exit   Enter your choice: 3  Pre-order traversal of the constructed AVL tree: 15 10 20    Operations:   1. Insert element 2. Delete element 3. Display tree 4. Exit   Enter your choice: 2  Enter the number to delete: 10 | 90 |

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| Operations:   1. Insert element 2. Delete element 3. Display tree 4. Exit   Enter your choice: 3  Pre-order traversal of the constructed AVL tree: 15 20    Operations:   1. Insert element 2. Delete element 3. Display tree 4. Exit   Enter your choice: 4 Exiting...                                                                **Result:**  Thus the code is implemented and executed successfully. | 91 |

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| 92     |  |  |  | | --- | --- | --- | | **Ex. No.: 11** | **Graph Traversal** | **Date:** |     **Write a C program to create a graph and perform a Breadth First Search and Depth First Search.**        **Aim:**  To create a graph and perform a Breadth First Search and Depth First Search.        **Algorithm:**     1. Start 2. Create a node which contains vertex and next as their members. 3. Allocates memory dynamically for nodes and the graph structure using malloc(). 4. Create a graph with a specified number of vertices and initialize adjacency lists. 5. Create a function to add the edges between the vertices 6. Performs BFS traversal starting from a given vertex using a queue data structure to maintain order. 7. Conducts DFS traversal starting from a specified vertex, employing recursion to exploregraph branches. 8. Displays the adjacency list representation of the graph and the traversal sequences. for both BFS and DFS. 9. End |

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| **Program:**    #include <stdio.h>  #include <stdlib.h>  #define MAX 100    struct Node { int vertex; struct Node\* next;  };    struct Node\* createNode(int v);    struct Graph { int numVertices; struct Node\*\* adjLists; int\* visited;  };    struct Graph\* createGraph(int vertices);    void addEdge(struct Graph\* graph, int src, int dest); void printGraph(struct Graph\* graph); void BFS(struct Graph\* graph, int startVertex); void DFS(struct Graph\* graph, int startVertex); void DFSUtil(struct Graph\* graph, int vertex);    int main() {  struct Graph\* graph = createGraph(4); addEdge(graph, 0, 1); addEdge(graph, 0, 2); addEdge(graph, 1, 2); addEdge(graph, 2, 0); addEdge(graph, 2, 3); addEdge(graph, 3, 3); | 93 |

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| printf("Graph:\n"); printGraph(graph);    printf("\nBFS Traversal:\n");  BFS(graph, 2);    printf("\nDFS Traversal:\n"); DFS(graph, 2); return 0;  }    struct Node\* createNode(int v) {  struct Node\* newNode = (struct Node\*)malloc(sizeof(struct Node)); newNode->vertex = v; newNode->next = NULL; return newNode;  }    struct Graph\* createGraph(int vertices) {  struct Graph\* graph = (struct Graph\*)malloc(sizeof(struct Graph)); graph->numVertices = vertices;  graph->adjLists = (struct Node\*\*)malloc(vertices \* sizeof(struct Node\*)); graph->visited = (int\*)malloc(vertices \* sizeof(int));    for (int i = 0; i < vertices; i++) { graph->adjLists[i] = NULL; graph->visited[i] = 0;  }  return graph;  }    void addEdge(struct Graph\* graph, int src, int dest) { struct Node\* newNode = createNode(dest); newNode->next = graph->adjLists[src]; graph->adjLists[src] = newNode; | 94 |

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| newNode = createNode(src);  newNode->next = graph->adjLists[dest]; graph->adjLists[dest] = newNode;  }    void printGraph(struct Graph\* graph) { for (int v = 0; v < graph->numVertices; v++) { struct Node\* temp = graph->adjLists[v]; printf("Vertex %d: ", v); while (temp) {  printf("%d -> ", temp->vertex); temp = temp->next;  }  printf("NULL\n");  }  }    void BFS(struct Graph\* graph, int startVertex) { int queue[MAX]; int front = 0, rear = 0;    graph->visited[startVertex] = 1; queue[rear++] = startVertex;    while (front < rear) {  int currentVertex = queue[front++]; printf("Visited %d\n", currentVertex);    struct Node\* temp = graph->adjLists[currentVertex]; while (temp) {  int adjVertex = temp->vertex; if (graph->visited[adjVertex] == 0) { graph->visited[adjVertex] = 1; queue[rear++] = adjVertex;  } | 95 |

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| temp = temp->next;  }  }  }    void DFSUtil(struct Graph\* graph, int vertex) { struct Node\* temp = graph->adjLists[vertex]; graph->visited[vertex] = 1; printf("Visited %d\n", vertex);    while (temp) {  int adjVertex = temp->vertex; if (graph->visited[adjVertex] == 0) {  DFSUtil(graph, adjVertex);  }  temp = temp->next;  }  }    void DFS(struct Graph\* graph, int startVertex) { for (int i = 0; i < graph->numVertices; i++) { graph->visited[i] = 0;  }  DFSUtil(graph, startVertex);  } | 96 |

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| **Output:**    Graph:  Vertex 0: 2->2->1-> NULL  Vertex 1: 2->0-> NULL  Vertex 2: 3->0->1->0-> NULL  Vertex 3: 3->3->2 -> NULL    BFS Traversal:  Visited 2  Visited 3  Visited 0 Visited 1    DFS Traversal:  Visited 2  Visited 3  Visited 0 Visited 1                                    **Result:**  Thus the program successfully implemented and executed. | 97 |

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| 98     |  |  |  | | --- | --- | --- | | **Ex. No.: 12** | **Topological Sorting** | **Date:** |     **Write a C program to create a graph and display the ordering of vertices.**          **Aim:**  Write a C program to create a graph and display the ordering of vertices (TOPOLOGICAL SORT)      **Algorithm:**    Step 1: Find the indegree for every vertex.  Step 2: Place the vertices whose indegree is 0 on the empty queue.  Step 3: Dequeue the vertex v and decrement the indegree of all its adjacent vertices.  Step 4: Enqueue the vertex on the queue if its indegree falls to zero.  Step 5: Repeat from step 3 until the queue becomes empty.  Step 6: The topological ordering is the order in which the vertices dequeue. |

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| **Program:**    #include <stdio.h> #include <stdlib.h> typedef struct Node Node; typedef struct Node\* pos; typedef struct Node\* Vert; typedef struct Graph\_parts\* Graph; typedef int Queue;    int front=-1,rear=-1;  Queue Q[50];    void enqueue(int n)  {  if(front==-1) front++; rear++;  Q[rear]=n;  }    int dequeue()  {  int p=Q[front]; if(front==rear)  {  front=-1; rear=-1;  } else front++; return p;  } | | 99 |
| struct Node  {  int data; pos next;  };    struct Graph\_parts  {  int vertices; int edges;  Vert\* List;  };    void Link(Graph G, int v1, int v2)  {  Vert n = (Vert)malloc(sizeof(Node)); if(n!=NULL)  {  n->data = v2; pos p=G->List[v1]; n->next=p->next; p->next=n;  }  }    void Get\_edges(Graph G)  {  int v1,v2,cost;  printf("Enter the edges:\n"); for(int i=0;i<G->edges;i++)  {  printf("=> ");  scanf("%d %d", &v1, &v2);  Link(G,v1,v2);  }  } | 100 | |

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| Graph Create\_graph()  {  Graph G = (Graph)malloc(sizeof(struct Graph\_parts)); if(G!=NULL)  {  printf("Enter the number of vertices in graph: "); scanf("%d", &G->vertices);  printf("Vertices are from 0 to %d\n",G->vertices-1);    printf("\nEnter the number of edges: "); scanf("%d",&G->edges);    G->List = (Vert\*)malloc(sizeof(Node) \* G->vertices); if(G->List!=NULL)  {  for (int i = 0; i < G->vertices; i++)  {  G->List[i] = (Vert)malloc(sizeof(struct Node));  }  }  Get\_edges(G); return G;  }  }    void Display(Graph G)  {  printf("\nDisplaying the Graph using List\n\n"); for (int i = 0; i < G->vertices; i++)  {  struct Node\* p = G->List[i]; printf("%d => ", i); p=p->next; | 101 |

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| while (p != NULL)  {  printf("%d ", p->data); p = p->next;  }  printf("\n");  }  }    void mark\_all\_zeros(int v[],int in[],int size)  {  for(int i=0;i<size;i++)  {  in[i]=0; v[i]=0;  }  }    void find\_indegree(Graph G,int in\_deg[])  { pos p;  for(int i=0;i<G->vertices;i++)  {  p=G->List[i]->next; while(p!=NULL)  {  in\_deg[p->data]++; p=p->next;  }  }  } | 102 |

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| void Topo\_sort(Graph G,int vis[],int in\_deg[])  {  int arr[G->vertices]; int s=0; int i,j=0;  while(j<G->vertices)  {  for(i=0;i<G->vertices;i++)  {  if(in\_deg[i]==0 && vis[i]==0)  {  enqueue(i); vis[i]=1;  }  }  if(front!=-1)  {  int n=dequeue(); arr[s]=n; s++;  pos p=G->List[n]->next; while(p!=NULL)  {  in\_deg[p->data]--; p=p->next;  } } else break; j++;  }  if(j==G->vertices)  {  printf("\nTopological sort for the given graph is:\n"); | 103 |

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| for(int k=0;k<G->vertices;k++)  {  printf("%d ",arr[k]);  }  } else  {  printf("Graph has a cycle");  }  }    void main()  {  Graph G=Create\_graph(); Display(G);  int visited[G->vertices]; int indegree[G->vertices];  mark\_all\_zeros(visited,indegree,G->vertices); find\_indegree(G,indegree);  Topo\_sort(G,visited,indegree);  } | 104 |

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| **Output:**    Enter the number of vertices in graph: 3  Vertices are from 0 to 2 Enter the number of edges: 3 Enter the edges:  => 0 1  => 0 2  => 1 2  Displaying the Graph using List   1. => 2 1 2. => 2 3. =>   Topological sort for the given graph is: 0 1 2                                **Result:**  Thus the program successfully implemented and executed. | 105 |

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| 106     |  |  |  | | --- | --- | --- | | **Ex. No.: 13** | **Graph Traversal** | **Date:** |     **Write a C program to create a graph and find a minimum spanning tree using prims algorithm.**    **Aim:**  To write a c program to create a graph and find a minimum spanning tree using prim’s  algorithm.    **Algorithm:**     1. Initialize `key[]` to `INT\_MAX`, `key[0]` to 0, `mstSet[]` to `false`, and `parent[]` to `-1`. 2. For count` from 0 to `numvertex 1:    * Select vertex `u` with minimum `key[u]` that is not `mstSet`.    * Set `mstSet[u]` to `true`.    * For each adjacent vertex `v` of `u`:   If `weight(u, v) < key [v]` and `v` is not in `mstset`, update `key[v]` and set `parent[v]` to `u`.   1. Repeat until all vertices are processed. |

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| **Program:**    #include <stdio.h>  #include <stdlib.h>  #include <stdbool.h>  #define infinity 10000;    struct node { int vertex; int w;  struct node \*next;  };    struct graph { int numvertex; struct node \*\*adjlist;  };    struct node\* create\_node(int vertex, int w) {  struct node \*new = (struct node\*)malloc(sizeof(struct node)); if (!new) {  printf("Memory allocation error\n"); exit(EXIT\_FAILURE);  }  new->vertex = vertex; new->w = w; new->next = NULL; return new;  }    struct graph\* create\_graph(int no) {  struct graph \*new = (struct graph\*)malloc(sizeof(struct graph)); if (!new) {  printf("Memory allocation error\n"); exit(EXIT\_FAILURE);  } | 107 |
| new->numvertex = no;  new->adjlist = (struct node\*\*)malloc(no \* sizeof(struct node\*)); if (!new->adjlist) {  printf("Memory allocation error\n"); exit(EXIT\_FAILURE);  }  for (int i = 0; i < no; i++) { new->adjlist[i] = NULL;  }  return new;  }    void add\_edge(struct graph \*g, int s, int d, int w) { struct node \*new = create\_node(d, w); new->next = g->adjlist[s]; g->adjlist[s] = new; new = create\_node(s, w); new->next = g->adjlist[d]; g->adjlist[d] = new;  }    struct graph\* input(struct graph \*g) { int no, d, s, w;  printf("ENTER THE NO. OF EDGES: "); scanf("%d", &no); for (int i = 0; i < no; i++) {  printf("Enter edge (source destination weight): "); scanf("%d %d %d", &s, &d, &w); add\_edge(g, s, d, w);  }  return g;  }    void print\_graph(struct graph \*g) { for (int i = 0; i < g->numvertex; i++) { struct node \*temp = g->adjlist[i]; | 108 |

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| printf("VERTEX %d\n", i); while (temp != NULL) {  printf("%d(%d) --> ", temp->vertex, temp->w); temp = temp->next;  }  printf("NULL\n");  }  }    void free\_graph(struct graph \*g) { for (int i = 0; i < g->numvertex; i++) { struct node \*temp = g->adjlist[i]; while (temp != NULL) { struct node \*to\_free = temp; temp = temp->next; free(to\_free);  }  }  free(g->adjlist); free(g);  }    void prim\_mst(struct graph \*g) { int numvertex = g->numvertex; int path[numvertex]; int dist[numvertex]; bool known[numvertex]; for (int i = 0; i < numvertex; i++) { dist[i] = infinity; known[i] = false;  }  dist[0] = 0; path[0] = -1; | 109 |

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| for (int count = 0; count < numvertex - 1; count++) { int u = -1; int min = infinity;  for (int v = 0; v < numvertex; v++) { if (!known[v] && dist[v] < min) { min = dist[v]; u = v;  }  }  if (u == -1) {  printf("Graph is disconnected\n"); return;  }  known[u] = true;  struct node \*temp = g->adjlist[u]; while (temp != NULL) { int v = temp->vertex;  if (!known[v] && temp->w < dist[v]) { path[v] = u; dist[v] = temp->w;  }  temp = temp->next;  }  }  printf("Path \tDistance\n"); for (int i = 1; i < numvertex; i++) { if (path[i] != -1) {  printf("%d - %d \t%d \n", path[i], i, dist[i]);  }  }  } | 110 |

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| int main() {  int n;  printf("ENTER THE NO. OF NODES: "); scanf("%d", &n); if (n <= 0) {  printf("Number of nodes must be greater than 0\n"); return -1;  }  struct graph \*g = create\_graph(n); input(g); print\_graph(g);  printf("\n\nMinimum Spanning Tree (MST) using Prim's Algorithm:\n\n"); prim\_mst(g); free\_graph(g); return 0;  } | 111 |

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| **Output:**    ENTER THE NO. OF NODES: 7  ENTER THE NO. OF EDGES: 9    Enter edge (source destination weight): 0 1 28  Enter edge (source destination weight): 1 2 16  Enter edge (source destination weight): 2 3 12  Enter edge (source destination weight): 3 4 22  Enter edge (source destination weight): 4 5 25  Enter edge (source destination weight): 5 0 10  Enter edge (source destination weight): 4 6 24  Enter edge (source destination weight): 2 6 18 Enter edge (source destination weight): 6 1 14    VERTEX 0  5(10) --> 1(28) --> NULL  VERTEX 1  6(14) --> 2(16) --> 0(28) --> NULL  VERTEX 2  6(18) --> 3(12) --> 1(16) --> NULL  VERTEX 3  4(22) --> 2(12) --> NULL  VERTEX 4  6(24) --> 5(25) --> 3(22) --> NULL  VERTEX 5  0(10) --> 4(25) --> NULL  VERTEX 6  1(14) --> 2(18) --> 4(24) --> NULL      Minimum Spanning Tree (MST) using Prim's Algorithm:    Path Distance | | 112 |
| 2 - 1 | 16 |  |
| 3 - 2 | 12 |  |
| 4 - 3 | 22 |  |
| 5 - 4 | 25 |  |
| 0 - 5 | 10 |  |
| 1 - 6 | 14 |  |
| **Result:**  Thus, the code is implemented and executed successfully. | |  |

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| 113       |  |  |  | | --- | --- | --- | | **Ex. No.: 14** | **Graph Traversal** | **Date:** |     **Write a C program to create a graph and find the shortest path using Dijikstra’s Algorithm.**        **Aim:**  To write a c program to create a graph and find the shortest path using dijikstras  algorithm.      **Algorithm:**     1. Initialize `dist[] to `INT\_MAX`, `dist[src]` to 0, and `known []` to `false`. 2. For count` from 0 to `numvertex 1:    * Select vertex `u` with minimum `dist[u]` that is not `known`.    * Set `known [u]` to `true`.    * For each adjacent vertex `v` of `u`:   If`dist[u] + weight(u, v) < dist[v]`, update `dist[v]` and set `path[v]` to `u`.   1. Repeat until all vertices are processed | |
| **Program:**    #include <stdio.h>  #include <stdlib.h>  #include <limits.h>  #include <stdbool.h>    struct node { int vertex; int w;  struct node \*next;  };    struct graph { int numvertex; struct node \*\*adjlist;  };    struct node\* create\_node(int vertex, int w) {  struct node \*new = (struct node\*)malloc(sizeof(struct node)); if (!new) {  fprintf(stderr, "Memory allocation error\n"); exit(EXIT\_FAILURE);  }  new->vertex = vertex; new->w = w; new->next = NULL; return new;  }    struct graph\* create\_graph(int no) {  struct graph \*new = (struct graph\*)malloc(sizeof(struct graph)); if (!new) {  fprintf(stderr, "Memory allocation error\n"); exit(EXIT\_FAILURE);  } | 114 |

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| new->numvertex = no;  new->adjlist = (struct node\*\*)malloc(no \* sizeof(struct node\*)); if (!new->adjlist) {  fprintf(stderr, "Memory allocation error\n"); exit(EXIT\_FAILURE);  }  for (int i = 0; i < no; i++) { new->adjlist[i] = NULL;  }  return new;  }    void add\_edge(struct graph \*g, int s, int d, int w) { struct node \*new = create\_node(d, w); new->next = g->adjlist[s]; g->adjlist[s] = new; new = create\_node(s, w); new->next = g->adjlist[d]; g->adjlist[d] = new;  }    struct graph\* input(struct graph \*g) { int no, d, s, w;  printf("ENTER THE NO. OF EDGES: "); scanf("%d", &no); for (int i = 0; i < no; i++) {  printf("Enter edge (source destination weight): "); scanf("%d %d %d", &s, &d, &w); add\_edge(g, s, d, w);  }  return g;  } | 115 |

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| void print\_graph(struct graph \*g) { for (int i = 0; i < g->numvertex; i++) { struct node \*temp = g->adjlist[i]; printf("VERTEX %d\n", i); while (temp != NULL) {  printf("%d(%d) --> ", temp->vertex, temp->w); temp = temp->next;  }  printf("NULL\n");  }  }    void free\_graph(struct graph \*g) { for (int i = 0; i < g->numvertex; i++) { struct node \*temp = g->adjlist[i]; while (temp != NULL) { struct node \*to\_free = temp; temp = temp->next; free(to\_free);  }  }  free(g->adjlist); free(g);  }    void print\_path(int path[], int vertex) { if (path[vertex] == -1) { printf("%d", vertex); return;  }  print\_path(path, path[vertex]); printf(" -> %d", vertex);  } | 116 |

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| void dijkstra(struct graph \*g, int src) { int numvertex = g->numvertex; int dist[numvertex]; bool known[numvertex]; int path[numvertex];  for (int i = 0; i < numvertex; i++) { dist[i] = INT\_MAX; known[i] = false; path[i] = -1;  }  dist[src] = 0;  for (int count = 0; count < numvertex - 1; count++) { int u = -1;  int min = INT\_MAX;  for (int v = 0; v < numvertex; v++) { if (!known[v] && dist[v] < min) { min = dist[v]; u = v;  }  }  if (u == -1) {  printf("Graph is disconnected\n"); return;  }  known[u] = true;  struct node \*temp = g->adjlist[u]; while (temp != NULL) { int v = temp->vertex;  if (!known[v] && dist[u] != INT\_MAX && dist[u] + temp->w < dist[v]) { dist[v] = dist[u] + temp->w; path[v] = u;  }  temp = temp->next;  }  } | 117 |
| printf("Vertex \t Distance from Source \t Path\n"); for (int i = 0; i < numvertex; i++) { if (i != src && dist[i] != INT\_MAX) { printf("%d \t\t %d \t\t\t\t\t ", i, dist[i]); print\_path(path, i); printf("\n");  }  }  }    int main() {  int n;  printf("ENTER THE NO. OF NODES: "); scanf("%d", &n); if (n <= 0) {  printf("Number of nodes must be greater than 0\n"); return -1;  }  struct graph \*g = create\_graph(n); input(g); print\_graph(g); int src;  printf("Enter the source vertex: "); scanf("%d", &src); if (src < 0 || src >= n) {  printf("Invalid source vertex\n"); free\_graph(g); return -1;  }  printf("Shortest Paths using Dijkstra's Algorithm:\n"); dijkstra(g, src); free\_graph(g); return 0;  } | 118 |

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| **Output:**    ENTER THE NO. OF NODES: 4  ENTER THE NO. OF EDGES: 6    Enter edge (source destination weight): 0  1  10  Enter edge (source destination weight): 0  2  20  Enter edge (source destination weight): 0  3  30  Enter edge (source destination weight): 1  0  40  Enter edge (source destination weight): 1  2  50  Enter edge (source destination weight): 1  3  60    VERTEX 0  1(40) --> 3(30) --> 2(20) --> 1(10) --> NULL  VERTEX 1  3(60) --> 2(50) --> 0(40) --> 0(10) --> NULL  VERTEX 2  1(50) --> 0(20) --> NULL  VERTEX 3  1(60) --> 0(30) --> NULL    Enter the source vertex: 3    Shortest Paths using Dijkstra's Algorithm:  Vertex Distance from Source Path   1. 30 3 -> 0 2. 40 3 -> 0 -> 1 3. 50 3 -> 0 -> 2           **Result:**  Thus, the code is implemented and executed successfully. | 119 |

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| 120     |  |  |  | | --- | --- | --- | | **Ex. No.: 15** | **Sorting** | **Date:** |     **Write a C program to take n numbers and sort the numbers in ascending order. Try to implement the same using following sorting techniques.**   1. **Quick Sort** 2. **Merge Sort**     **Aim:**  To write a C program to take n numbers and sort the numbers in ascending order. To  implement the same using following sorting techniques:    1.Quick Sort  2.Merge Sort    **Algorithm:**    **Quick Sort:**  Step 1: Start the program  Step 2: Provide void swap  Step 3: Accept integer partition  Step 4: Provide void quicksort  Step 5: Accept int n = sizeof (arr) /sizeof (arr[0])  Step 6: Print original array  Step 7: Print sorted array  Step 8: Stop the program    **Merge Sort:**  Step 1: Start the program  Step 2: Provide void merge  Step 3: Provide void merge sort  Step 4: Provide void print array  Step 5: Print the given array  Step 6: Print the sorted array  Step 7: Stop the program |

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| Program:    **MERGE SORT:**    #include <stdio.h>  #include <stdlib.h>    void merge(int arr[], int l, int m, int r)  {  int i, j, k; int n1 = m - l + 1; int n2 = r - m;    int L[n1], R[n2];    for (i = 0; i < n1; i++) L[i] = arr[l + i]; for (j = 0; j < n2; j++)  R[j] = arr[m + 1 + j];    i = 0; j = 0; k = l;    while (i < n1 && j < n2) { if (L[i] <= R[j]) { arr[k] = L[i]; i++;  } else {  arr[k] = R[j]; j++;  } k++;  } | 121 |

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| while (i < n1) { arr[k] = L[i]; i++; k++;  }    while (j < n2) { arr[k] = R[j]; j++; k++;  }  }    void mergeSort(int arr[], int l, int r)  {  if (l < r) {  // Same as (l+r)/2, but avoids // overflow for large l and r int m = l + (r - l) / 2;    // Sort first and second halves mergeSort(arr, l, m); mergeSort(arr, m + 1, r);    merge(arr, l, m, r);  }  }    void printArray(int A[], int size)  { int i;  for (i = 0; i < size; i++) printf("%d ", A[i]); printf("\n");  } | 122 |

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| int main()  { int n;  printf("Enter the size of the array: "); scanf("%d",&n); int arr[n];    printf("\nEnter array elements:\n"); for (int i = 0; i < n; i++) { scanf("%d", &arr[i]);  }  printf("Given array is \n"); printArray(arr, n);    mergeSort(arr, 0, n - 1);    printf("\nSorted array is \n"); printArray(arr, n); return 0;  } | 123 |

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| **Output:**    Enter the size of the array: 6    Enter array elements:  12  11  13  5  7  6  Given array is  12 11 13 5 7 6    Sorted array is  5 6 7 11 12 13                  **Result:**  The code is verified and implemented successfully | 124 |

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| **QUICK SORT:**    #include <stdio.h> void swap(int\* a, int\* b)  {  int temp = \*a;  \*a = \*b;  \*b = temp;  }    int partition(int arr[], int low, int high)  {    int pivot = arr[low]; int i = low; int j = high;    while (i < j) {  while (arr[i] <= pivot && i <= high - 1) { i++;  }  while (arr[j] > pivot && j >= low + 1) { j--; }  if (i < j) {  swap(&arr[i], &arr[j]);  }  }  swap(&arr[low], &arr[j]); return j;  } | 125 |

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| void quickSort(int arr[], int low, int high)  {  if (low < high) {  int partitionIndex = partition(arr, low, high); quickSort(arr, low, partitionIndex - 1); quickSort(arr, partitionIndex + 1, high);  }  }    int main()  { int n;  printf("Enter the size of the array: "); scanf("%d",&n); int arr[n];    printf("\nEnter array elements:\n"); for (int i = 0; i < n; i++) { scanf("%d", &arr[i]);  }    printf("Original array: "); for (int i = 0; i < n; i++) { printf("%d ", arr[i]);  }    quickSort(arr, 0, n - 1);    // printing the sorted array printf("\nSorted array: "); for (int i = 0; i < n; i++) { printf("%d ", arr[i]);  }  return 0;  } | 126 |
| **Output :**    Enter the size of the array: 9    Enter the elements: 9  19  17  15  12  16  18  4  11  13    Original array:  19 17 15 12 16 18 4 11 13    Sorted array using quick sort:  4 11 12 13 15 16 17 18 19                  **Result:**  The code is verified and implemented successfully | 127 |

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| 128   |  |  |  | | --- | --- | --- | | **Ex. No.: 16** | **Hashing** | **Date:** |     **Write a C program to create a hash table and perform collision resolution using the following techniques.**   1. **Open addressing** 2. **Closed Addressing** 3. **Rehashing**       **Aim:**  To write a c program to implement various hashing techniques    **Algorithm:**   1. **Initialize Table:** Create a hash table with a specified size, ensuring it meets a minimum size requirement. 2. **Determine Prime Size:** Calculate the next prime number greater than or equal to the specified table size to reduce collisions. 3. **Allocate Memory:** Allocate memory for the hash table and initialize its cell array. 4. **Hash Function:** Implement a hash function to map keys to indices in the hash table. 5. **Find Position:** Search for a position in the hash table for insertion or retrieval, handling collisions using linear probing. 6. **Insertion:** Insert a key into the hash table, marking the corresponding cell as legitimate if empty. 7. **Display:** Traverse the hash table and print the contents of each cell, displaying both indices and associated data. 8. **Check Fullness:** Determine whether the hash table is full, preventing further insertions if all cells are legitimate. 9. **User Interaction:** Allow users to choose operations such as insertion or display, ensuring appropriate responses to fullness or invalid choices. 10. **Termination:** Gracefully terminate the program upon user request, indicating the end of operations. |

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| **Program: (Linear Probing)**    #include <stdio.h>  #include<stdlib.h> #define MINSIZE 7 typedef int index; typedef index position; typedef struct hash\_entry cell; typedef struct H\_table\* Hashtable; enum entry { Legitimate, Empty, Deleted };    struct hash\_entry  { int data; enum entry info;  };    struct H\_table  { int table\_size; cell\* cell\_array;  }; | 129 |

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| int next\_prime(int table\_size)  { int i=table\_size,f; while(1)  { f=1; for(int j=2;j<i;j++)  {  if(i%j==0)  { f=0; break;  }  }  if(f==1) return i; i++;  }  }  index Hash(int key,int table\_size)  {  return key % table\_size;  } | 130 |

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| Hashtable Create\_table(int table\_size)  {  Hashtable H; if(table\_size < MINSIZE)  {  printf("Table size too small"); return NULL;  }  H=(Hashtable)malloc(sizeof(struct H\_table)); if(H==NULL)  {  printf("Out of space"); return NULL;  }  H->table\_size = next\_prime(table\_size);  H->cell\_array = (cell\*) malloc(sizeof(cell) \* H->table\_size); if(H->cell\_array==NULL)  {  printf("Out of space"); return NULL;  }  for(int i=0;i< H->table\_size;i++)  {  H->cell\_array[i].info=Empty;  } | 131 |

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| return H;  }  position find(int key,Hashtable H)  { position cur; int collision=0; cur=Hash(key,H->table\_size); while(H->cell\_array[cur].info!=Empty && H->cell\_array[cur].data != key)  {  cur=(cur+1) % H->table\_size;  }  return cur;  }  void insert(int key,Hashtable H)  {  position pos=find(key,H); if(H->cell\_array[pos].info!=Legitimate)  {  H->cell\_array[pos].info=Legitimate;  H->cell\_array[pos].data=key;  }  } | 132 |

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| void display(Hashtable H)  {  for(int i=0;i<H->table\_size;i++)  {  printf("%d => %d\n",i,H->cell\_array[i].data);  }  }  int isFull(Hashtable H)  { int count=0; for(int i=0;i<H->table\_size;i++)  {  if(H->cell\_array[i].info==Legitimate) count++;  }  if(count==H->table\_size) return 1;  else return 0;  }  void main()  { int size; printf("Enter size of the table: "); scanf("%d",&size);  Hashtable H1=Create\_table(size); | 133 |

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| printf("Hash table size: %d\n",H1->table\_size); if(H1!=NULL)  { int d,op; do  {  printf("\nChoose operation: 1) Insert 2) Display: "); scanf("%d",&op);    switch(op)  { case 1:  if(isFull(H1))  {  printf("Hash Table is full...\n"); break;  }  printf("Enter the data to be inserted: "); scanf("%d",&d); insert(d,H1);  break; case 2:  printf("\nLinear probing hash table\n\n"); display(H1);  break; | 134 |

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| case 0:  printf("Operation terminated");  break; default:  printf("Invalid operation...\n");  }  }while(op);  }  }    **Quadratic Probing:**  #include <stdio.h>  #include<stdlib.h> #define MINSIZE 7 typedef int index; typedef index position; typedef struct hash\_entry cell; typedef struct H\_table\* Hashtable; enum entry { Legitimate, Empty, Deleted };    struct hash\_entry  { int data; enum entry info;  }; | 135 |

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| struct H\_table  { int table\_size; cell\* cell\_array;  };  int next\_prime(int table\_size)  { int i=table\_size,f; while(1)  { f=1; for(int j=2;j<i;j++)  {  if(i%j==0)  { f=0; break;  }  }  if(f==1) return i; i++;  }  } | 136 |

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| index Hash(int key,int table\_size)  {  return key % table\_size;  }  Hashtable Create\_table(int table\_size)  {  Hashtable H; if(table\_size < MINSIZE)  {  printf("Table size too small"); return NULL;  }  H=(Hashtable)malloc(sizeof(struct H\_table)); if(H==NULL)  {  printf("Out of space"); return NULL;  }  H->table\_size = next\_prime(table\_size);  H->cell\_array = (cell\*) malloc(sizeof(cell) \* H->table\_size); if(H->cell\_array==NULL)  {  printf("Out of space"); return NULL;  } | 137 |

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| for(int i=0;i< H->table\_size;i++)  {  H->cell\_array[i].info=Empty;  }  return H;  }    position find(int key,Hashtable H)  { position cur; int collision=0; cur=Hash(key,H->table\_size); while(H->cell\_array[cur].info!=Empty && H->cell\_array[cur].data != key)  {  cur=(cur+(2\*(++collision)-1)) % H->table\_size;  }  return cur;  }  void insert(int key,Hashtable H)  {  position pos=find(key,H); if(H->cell\_array[pos].info!=Legitimate)  {  H->cell\_array[pos].info=Legitimate;  H->cell\_array[pos].data=key; | 138 |

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| }  }    void display(Hashtable H)  {  for(int i=0;i<H->table\_size;i++)  {  printf("%d => %d\n",i,H->cell\_array[i].data);  }  }  int isFull(Hashtable H)  { int count=0; for(int i=0;i<H->table\_size;i++)  {  if(H->cell\_array[i].info==Legitimate) count++;  }  if(count==H->table\_size) return 1;  else return 0;  } | 139 |

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| void main()  { int size; printf("Enter size of the table: "); scanf("%d",&size);  Hashtable H1=Create\_table(size); printf("Hash table size: %d\n",H1->table\_size); if(H1!=NULL)  { int d,op; do  {  printf("\nChoose operation: 1) Insert 2) Display: "); scanf("%d",&op); switch(op)  { case 1:  if(isFull(H1))  {  printf("Hash Table is full...\n"); break;  }  printf("Enter the data to be inserted: "); scanf("%d",&d); insert(d,H1); | 140 |

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| break; case 2:  printf("\nQuadratic probing hash table\n\n");  display(H1);  break; case 0:  printf("Operation terminated");  break; default:  printf("Invalid operation...\n");  }  }while(op);  }  }    **Rehashing:**  #include <stdio.h>  #include<stdlib.h> #define MINSIZE 7 typedef int index; typedef index position; typedef struct hash\_entry cell; typedef struct H\_table\* Hashtable; enum entry { Legitimate, Empty, Deleted }; | 141 |

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| struct hash\_entry  { int data; enum entry info;  };  struct H\_table  { int table\_size; cell\* cell\_array;  };  int next\_prime(int table\_size)  { int i=table\_size,f; while(1)  { f=1; for(int j=2;j<i;j++)  {  if(i%j==0)  { f=0; break;  }  }  if(f==1) return i; i++; | 142 |

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| }  }  int isFull(Hashtable H)  { int count=0; for(int i=0;i<H->table\_size;i++)  {  if(H->cell\_array[i].info==Legitimate) count++;  }  if(count>H->table\_size\*0.75) return 1;  else return 0;  }  index Hash(int key,int table\_size)  {  return key % table\_size;  }  Hashtable Create\_table(int table\_size)  {  Hashtable H; if(table\_size < MINSIZE)  {  printf("Table size too small"); return NULL;  }  H=(Hashtable)malloc(sizeof(struct H\_table)); | 143 |

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| if(H==NULL)  {  printf("Out of space"); return NULL;  }  H->table\_size = next\_prime(table\_size);  H->cell\_array = (cell\*) malloc(sizeof(cell) \* H->table\_size); if(H->cell\_array==NULL)  {  printf("Out of space"); return NULL;  }  for(int i=0;i< H->table\_size;i++)  {  H->cell\_array[i].info=Empty;  }  return H; }    position find(int key,Hashtable H)  { position cur; int collision=0; cur=Hash(key,H->table\_size); while(H->cell\_array[cur].info!=Empty && H->cell\_array[cur].data != key)  {  cur=(cur+1) % H->table\_size;  } | 144 |

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| return cur;  }  void insert(int key,Hashtable H)  {  position pos=find(key,H); if(H->cell\_array[pos].info!=Legitimate)  {  H->cell\_array[pos].info=Legitimate;  H->cell\_array[pos].data=key;  }  }  Hashtable Rehash(Hashtable H1)  {  Hashtable H2=Create\_table(H1->table\_size\*2); for(int i=0;i<H1->table\_size;i++)  {  if(H1->cell\_array[i].info==Legitimate) insert(H1->cell\_array[i].data,H2);  }  return H2;  }  void display(Hashtable H)  {  for(int i=0;i<H->table\_size;i++)  {  printf("%d => %d\n",i,H->cell\_array[i].data);  } | 145 |

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| }  void main()  { int size; printf("Enter size of the table: "); scanf("%d",&size);  Hashtable H1=Create\_table(size); printf("Hash table size: %d\n",H1->table\_size); if(H1!=NULL)  { int d,op; do  {  printf("\nChoose operation: 1) Insert 2) Display: "); scanf("%d",&op); switch(op)  { case 1:  if(isFull(H1))  {  printf("\nRehashing the table from %d to",H1->table\_size); H1=Rehash(H1); printf(" %d...\n\n",H1->table\_size);  }  printf("Enter the data to be inserted: "); scanf("%d",&d); insert(d,H1); | 146 |

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| break; case 2:  printf("\nLinear probing hash table\n\n"); display(H1); break;  case 0:  printf("Operation terminated");  break; default:  printf("Invalid operation...\n");  }  }while(op);  }  } | 147 |

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| **Output:**  Enter size of the table: 10  Hash table size: 11  Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 7  Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 18  Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 45  Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 93  Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 17    Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 69  Choose operation: 1) Insert 2) Display: 2 | 148 |

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| 149  Linear probing hash table     1. => 0 2. => 45 3. => 0 4. => 69 5. => 0 6. => 93 7. => 17 8. => 7 9. => 18 10. => 0 11. => 0                     **Result:**    Thus the program has been successfully executed. |

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| **SEPARATE CHAINING:**    **Program:**  #include <stdio.h>  #include<stdlib.h>  #define MINSIZE 7    typedef int index; typedef struct Node\* position; typedef struct Node\*List; typedef struct H\_table\* Hashtable;    struct Node  { int data; position next;  };    struct H\_table  { int table\_size;  List\* List\_array;  }; | 150 |

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| int next\_prime(int table\_size)  { int i=table\_size,f; while(1)  { f=1; for(int j=2;j<i;j++)  {  if(i%j==0)  { f=0; break;  }  }  if(f==1) return i; i++;  }  }    index Hash(int key,int table\_size)  {  return key % table\_size;  } | 151 |

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| Hashtable Create\_table(int table\_size)  {  Hashtable H; if(table\_size < MINSIZE)  {  printf("Table size too small"); return NULL;  }  H=(Hashtable)malloc(sizeof(struct H\_table)); if(H==NULL)  {  printf("Out of space"); return NULL;  }  H->table\_size = next\_prime(table\_size);  H->List\_array = (List\*) malloc(sizeof(List) \* H->table\_size);    if(H->List\_array==NULL)  {  printf("Out of space"); return NULL;  }  for(int i=0;i< H->table\_size;i++)  {  H->List\_array[i]=(position)malloc(sizeof(struct Node)); | 152 |

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| if(H->List\_array[i]==NULL)  {  printf("Out of space"); return NULL;  } else  {  H->List\_array[i]->next==NULL;  }  }  return H;  }  position find(int key,Hashtable H)  { position p;  List L;  L=H->List\_array[Hash(key,H->table\_size)]; p=L->next; while(p!=NULL && p->data!=key)  p=p->next; return p;} | 153 |

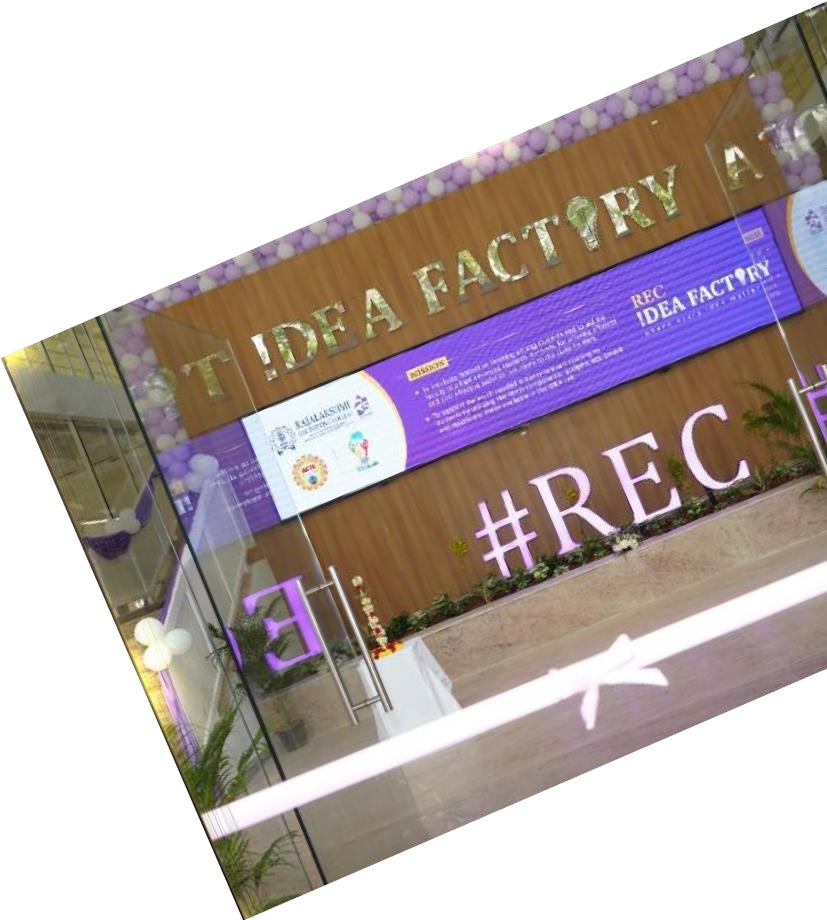
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| void insert(int key,Hashtable H)  { position p,new\_cell; List L; p=find(key,H); if(p==NULL)  {  new\_cell=(position)malloc(sizeof(struct Node)); if(new\_cell==NULL) printf("Out of space");  else  {  new\_cell->data=key;  L=H->List\_array[Hash(key,H->table\_size)]; new\_cell->next=L->next;  L->next=new\_cell;  }  }  }    void display(Hashtable H){ for(int i=0;i<H->table\_size;i++){ List L=H->List\_array[i]; printf("%d => ",i); position p=L->next; | 154 |

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| while(p!=NULL)  {  printf("%d ",p->data); p=p->next;  }  printf("\n");  }  }  int main()  { int size; printf("Enter size of the table: "); scanf("%d",&size);  Hashtable H1=Create\_table(size); printf("Hashtable Size: %d\n",H1->table\_size); if(H1!=NULL)  { int d,op; do  {  printf("\nChoose operation: 1) Insert 2) Display: "); scanf("%d",&op); | 155 |

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| --- | --- |
| switch(op)  { case 1:  printf("Enter the data to be inserted:"); scanf("%d",&d); insert(d,H1); break; case 2:  printf("\nSeparate Chaining hash table\n\n");  display(H1); break;  case 0:  printf("Operation terminated");  break; default:  printf("Invalid operation\n");  }  } while(op);  }  } | 156 |

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| --- |
| 157  **Output:**  Enter size of the table: 10  Hashtable Size: 11    Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 15    Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 25    Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 35    Choose operation: 1) Insert 2) Display: 2    Separate Chaining hash table     1. => 2. => 3. => 4. => 5. => 6. => 7. => 8. => 35 25 15 9. => 10. => 11. =>     Choose operation: 1) Insert 2) Display: 1  Enter the data to be inserted: 45    Choose operation: 1) Insert 2) Display: 2    Separate Chaining hash table     1. => 2. => 3. => 4. => 5. => 6. => 7. => 8. => 45 35 25 15 9. => 10. => 11. =>     Choose operation: 1) Insert 2) Display: 0  Operation terminated |

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| 158  **Result:**    Thus the Hashing function using separate chaining method was achieved and program has been successfully executed. |



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