RAJALAKSHMI ENGINEERING COLLEGE

An AUTONOMOUS Institution
Affiliated to ANNA UNIVERSITY, Chennai

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

CS23231 – DATA STRUCTURES

(*Regulation 2023*)

LAB MANUAL

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LESSON PLAN

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

LIST OF EXPERIMENTS	
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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
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Ex. No.: 1	Implementation of Single Linked List	Date: 23/2/24

Write a C p r o g r a m t o i m p l e m e n t t h e f o l l o w i n g o p e r a t i o n s o n S i n g l y L i n k e d L i s t.

(i)   **Insert a node in the beginning of a list.**

(ii)   **Insert a node after P**

(iii)   **Insert a node at the end of a list**

(iv)   **Find an element in a list**

(v)   **FindNext**

(vi)   **FindPrevious**

(vii)   **isLast**

(viii)   **isEmpty**

(ix)   **Delete a node in the beginning of a list.**

(x)   **Delete a node after P**

(xi)   **Delete a node at the end of a list**

(xii)   **Delete the List**

Algorithm:

```c
#include <stdio.h>
#include <malloc.h>

struct node {
    int data;
    struct node* next;
};
struct node* head = NULL;

void insertfront(int ele) {

    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = head;
        head = newnode;
    }
}

void insertend(int ele) {
    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = NULL;
```

```c
        if (head == NULL) {
            head = newnode;
        } else {
            struct node* t = head;
            while (t->next != NULL) {
                t = t->next;
            }
            t->next = newnode;
        }
    }
}

int listsize() {
    int count = 0;
    struct node* t = head;
    while (t != NULL) {
        count++;
        t = t->next;
    }
    return count;
}

void insertpos(int ele, int pos) {
    int ls = listsize();
    if ((head == NULL && pos != 1) || pos <= 0 || pos > ls + 1) {
        printf("\nInvalid position to insert a node\n");
        return;
    }

    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        if (pos == 1) {
            newnode->next = head;
            head = newnode;
        } else {
            struct node* temp = head;
            for (int count = 1; count < pos - 1; count++) {
                temp = temp->next;
            }
            newnode->next = temp->next;
            temp->next = newnode;
        }
    }
}

void findnext(int s) { struct
    node* temp = head;
    while (temp != NULL && temp->data != s) {
        temp = temp->next;
```

```c
    }
    if (temp != NULL && temp->next != NULL) {
        printf("\nNext element of %d is %d\n", s, temp->next->data);
    } else {
        printf("\nNo next element for %d\n", s);
    }
}

void findprev(int s) {
    if (head == NULL || head->data == s) {
        printf("\nNo previous element for %d\n", s);
        return;
    }
    struct node* temp = head;
    while (temp->next != NULL && temp->next->data != s) {
        temp = temp->next;
    }
    if (temp->next != NULL) {
        printf("\nPrevious element of %d is %d\n", s, temp->data);
    } else {
        printf("\nElement %d not found\n", s);
    }
}

void find(int s) {
    struct node* temp = head;
    while (temp != NULL && temp->data != s) {
        temp = temp->next;
    }
    if (temp != NULL) {
        printf("\nElement %d is present in the list\n", s);
    } else {
        printf("\nElement %d is not present in the list\n", s);
    }
}

void isempty() {
    if (head == NULL) {
        printf("\nList is empty\n");
    } else {
        printf("\nList is not empty\n");
    }
}

void deleteAtBeginning() {
    if (head != NULL) {
        struct node* temp = head;
        head = head->next;
        free(temp);
    }
```

```c
}

void deleteAtEnd() {
    if (head == NULL)
    {
        printf("\nList is empty\n");
        return;
    }
    if (head->next == NULL) {
        free(head);
        head = NULL;
    } else {
        struct node* temp = head;
        while (temp->next->next != NULL) {
            temp = temp->next;
        }
        free(temp->next);
        temp->next = NULL;
    }
}

void delete(int ele) {
    if (head == NULL) {
        printf("\nList is empty\n");
        return;
    }
    if (head->data == ele) {
        struct node* temp = head;
        head = head->next;
        free(temp);
    } else {
        struct node* temp = head;
        while (temp->next != NULL && temp->next->data != ele) {
            temp = temp->next;
        }
        if (temp->next != NULL) {
            struct node* delNode = temp->next;
            temp->next = temp->next->next;
            free(delNode);
        } else {
            printf("\nElement %d not found\n", ele);
        }
    }
}

void display() {
    struct node* t = head;
    while (t != NULL) {
        printf("%d\t", t->data);
        t = t->next;
    }
}
```

```c
        printf("\n");
    }

int main() {
    insertfront(5);
    insertfront(10);
    insertfront(20);
    insertend(30);
    insertend(40);
    display();

    printf("\nAfter inserting 15 at the 2nd position\n");
    insertpos(15, 2);
    display();

    findnext(30);
    findprev(30);

    find(15);
    isempty();

    printf("\nAfter deleting the first element\n");
    deleteAtBeginning();
    display();

    printf("\nAfter deleting the last element\n");
    deleteAtEnd();
    display();

    printf("\nAfter deleting element 15\n");
    delete(15);
    display();

    return 0;
}
```

Ex. No.: 2	Implementation of Doubly Linked List	Date: 11/3/24

Write a C p r o g r a m t o i m p l e m e n t t h e f o l l o w i n g o p e r a t i o n s o n D o u b l y L i n k e d L i s t.

(i)   Insertion

(ii)   Deletion

(iii)   Search

(iv)   Display

Algorithm:

```c
#include <stdio.h>
#include <malloc.h>

struct node {
    int data;
    struct node* next;
    struct node* prev;
};
struct node* head = NULL;
void insertfront(int ele) {
    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = head;
        newnode->prev = NULL;
        if (head != NULL) {
            head->prev = newnode;
        }
        head = newnode;
    }
}

void insertend(int ele) {
    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = NULL;
        if (head == NULL) {
            newnode->prev = NULL;
            head = newnode;
        } else {
            struct node* t = head;
            while (t->next != NULL) {
```

```
            t = t->next;
        }
        t->next = newnode;
        newnode->prev = t;
    }
}
}

int listsize() {
    int count = 0;
    struct node* t = head;
    while (t != NULL) {
        count++;
        t = t->next;
    }
    return count;
}

void insertpos(int ele, int pos) {
    int ls = listsize();
    if ((head == NULL && pos != 1) || pos <= 0 || pos > ls + 1) {
        printf("\nInvalid position to insert a node\n");
        return;
    }

    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        if (pos == 1) {
            newnode->next = head;
            newnode->prev = NULL;
            if (head != NULL) {
                head->prev = newnode;
            }
            head = newnode;
        } else {
            struct node* temp = head;
            for (int count = 1; count < pos - 1; count++) {
                temp = temp->next;
            }
            newnode->next = temp->next;
            newnode->prev = temp;
            if (temp->next != NULL) {
                temp->next->prev = newnode;
            }
            temp->next = newnode;
        }
    }
}
```

```c
void findnext(int s) { struct
    node* temp = head;
    while (temp != NULL && temp->data != s) {
        temp = temp->next;
    }
    if (temp != NULL && temp->next != NULL) {
        printf("\nNext element of %d is %d\n", s, temp->next->data);
    } else {
        printf("\nNo next element for %d\n", s);
    }
}


void findprev(int s) { struct
    node* temp = head;
    while (temp != NULL && temp->data != s) {
        temp = temp->next;
    }
    if (temp != NULL && temp->prev != NULL) {
        printf("\nPrevious element of %d is %d\n", s, temp->prev->data);
    } else {
        printf("\nNo previous element for %d\n", s);
    }
}


void find(int s) {
    struct node* temp = head;
    while (temp != NULL && temp->data != s) {
        temp = temp->next;
    }
    if (temp != NULL) {
        printf("\nElement %d is present in the list\n", s);
    } else {
        printf("\nElement %d is not present in the list\n", s);
    }
}


void isempty() {
    if (head == NULL) {
        printf("\nList is empty\n");
    } else {
        printf("\nList is not empty\n");
    }
}


void deleteAtBeginning() {
    if (head != NULL) {
        struct node* temp = head;
        head = head->next;
        if (head != NULL) {
            head->prev = NULL;
```

```c
        }
        free(temp);
    }
}

void deleteAtEnd() {
    if (head == NULL)
    {
        printf("\nList is empty\n");
        return;
    }
    if (head->next == NULL) {
        free(head);
        head = NULL;
    } else {
        struct node* temp = head;
        while (temp->next != NULL) {
            temp = temp->next;
        }
        temp->prev->next = NULL;
        free(temp);
    }
}

void delete(int ele) {
    if (head == NULL) {
        printf("\nList is empty\n");
        return;
    }
    if (head->data == ele) {
        struct node* temp = head;
        head = head->next;
        if (head != NULL) {
            head->prev = NULL;
        }
        free(temp);
    } else {
        struct node* temp = head;
        while (temp != NULL && temp->data != ele) {
            temp = temp->next;
        }
        if (temp != NULL) {
            if (temp->prev != NULL) {
                temp->prev->next = temp->next;
            }
            if (temp->next != NULL) {
                temp->next->prev = temp->prev;
            }
            free(temp);
        } else {
            printf("\nElement %d not found\n", ele);
```

```c
        }
    }
}

void display() {
    struct node* t = head;
    while (t != NULL) {
        printf("%d\t", t->data);
        t = t->next;
    }
    printf("\n");
}

int main() {
    insertfront(5);
    insertfront(10);
    insertfront(20);
    insertend(30);
    insertend(40);
    display();

    printf("\nAfter inserting 15 at the 2nd position\n");
    insertpos(15, 2);
    display();

    findnext(30);
    findprev(30);

    find(15);
    isempty();

    printf("\nAfter deleting the first element\n");
    deleteAtBeginning();
    display();

    printf("\nAfter deleting the last element\n");
    deleteAtEnd();
    display();

    printf("\nAfter deleting element 15\n");
    delete(15);
    display();

    return 0;
}
```

Ex. No.: 3	Polynomial Manipulation	Date: 8/3/24

Write a C program to implement the following operations on Singly Lin ked List.

(i) **Polynomial Addition**

(ii) **Polynomial Subtraction**

(iii) **Polynomial Multiplication**

Algorithm:

```c
#include <stdio.h>
#include <malloc.h>

struct node {
    int coeff;
    int exp;
    struct node* next;
    struct node* prev;
};

struct node* head1 = NULL;
struct node* head2 = NULL;
struct node* headResult = NULL;

void insertTerm(struct node** head, int coeff, int exp) {
    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->coeff = coeff;
        newnode->exp = exp;
        newnode->next = NULL;
        newnode->prev = NULL;
        if (*head == NULL) {
            *head = newnode;
        } else {
            struct node* t = *head;
            while (t->next != NULL) {
                t = t->next;
            }
            t->next = newnode;
            newnode->prev = t;
        }
    }
}

void display(struct node* head) {
    struct node* t = head;
    while (t != NULL) {
        if (t->coeff > 0 && t != head)
```

```c
            printf("+ ");
        printf("%dx^%d ", t->coeff, t->exp);
        t = t->next;
    }
    printf("\n");
}

struct node* addPolynomials(struct node* head1, struct node* head2) {
    struct node* result = NULL;
    struct node* t1 = head1;
    struct node* t2 = head2;

    while (t1 != NULL && t2 != NULL) {
        if (t1->exp == t2->exp) {
            insertTerm(&result, t1->coeff + t2->coeff, t1->exp);
            t1 = t1->next;
            t2 = t2->next;
        } else if (t1->exp > t2->exp) {
            insertTerm(&result, t1->coeff, t1->exp);
            t1 = t1->next;
        } else {
            insertTerm(&result, t2->coeff, t2->exp);
            t2 = t2->next;
        }
    }

    while (t1 != NULL) {
        insertTerm(&result, t1->coeff, t1->exp);
        t1 = t1->next;
    }

    while (t2 != NULL) {
        insertTerm(&result, t2->coeff, t2->exp);
        t2 = t2->next;
    }

    return result;
}

struct node* multiplyPolynomials(struct node* head1, struct node* head2) {
    struct node* result = NULL;
    struct node* t1 = head1;
    struct node* t2 = head2;

    while (t1 != NULL) {
        t2 = head2;
        while (t2 != NULL) {
            insertTerm(&result, t1->coeff * t2->coeff, t1->exp + t2->exp);
            t2 = t2->next;
        }
```

```
            t1 = t1->next;
        }
        struct node* t = result;
        struct node* tPrev = NULL;

        while (t != NULL && t->next != NULL) {
            tPrev = t;
            struct node* tNext = t->next;
            while (tNext != NULL) {
                if (t->exp == tNext->exp) {
                    t->coeff += tNext->coeff;
                    tPrev->next = tNext->next;
                    if (tNext->next != NULL) {
                        tNext->next->prev = tPrev;
                    }
                    free(tNext);
                    tNext = tPrev->next;
                } else {
                    tPrev = tNext;
                    tNext = tNext->next;
                }
            }
            t = t->next;
        }

        return result;
    }
    int main() {
        insertTerm(&head1, 5, 2);
        insertTerm(&head1, 4, 1);
        insertTerm(&head1, 2, 0);

        insertTerm(&head2, 5, 1);
        insertTerm(&head2, 5, 0);

        printf("Polynomial 1: ");
        display(head1);

        printf("Polynomial 2: ");
        display(head2);

        headResult = addPolynomials(head1, head2);
        printf("\nAddition Result: ");
        display(headResult);

        headResult = multiplyPolynomials(head1, head2);
        printf("\nMultiplication Result: ");
        display(headResult);

        return 0;}
```

Ex. No.: 4	Implementation of Stack using Array and Linked List Implementation	Date: 15/3/24

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**

(ii)   **Pop an element from a stack**

(iii)   **Return the Top most element from a stack**

(iv)   **Display the elements in a stack**

Algorithm:

```c
#include <stdio.h>
#include <malloc.h>

struct node {
    int data;
    struct node* next;
};
struct node* top = NULL;

void push(int ele) {

    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = top;
        top = newnode;
    }
}

int pop() {
    if (top == NULL) { printf("\nStack
        Underflow\n"); return -1;
    } else {
        int popped = top->data;
        struct node* temp = top;
        top = top->next;
        free(temp);
        return popped;
    }
}

int peek() {
    if (top != NULL) {
        return top->data;
    } else {
```

```c
        printf("\nStack is empty\n");
        return -1;
    }
}

int isEmpty() {
    return top == NULL;
}

void display() {
    struct node* t = top;
    while (t != NULL) {
        printf("%d\t", t->data);
        t = t->next;
    }
    printf("\n");
}

int main() {
    push(10);
    push(20);
    push(30);
    display();

    printf("Top element is %d\n", peek());

    printf("Popped element is %d\n", pop());
    display();

    printf("Popped element is %d\n", pop());
    display();
    printf("Is stack empty? %s\n", isEmpty() ? "Yes" : "No");

    printf("Popped element is %d\n", pop());

    display();

    printf("Is stack empty? %s\n", isEmpty() ? "Yes" : "No");

    return 0;
}
```

Ex. No.: 5	Infix to Postfix Conversion	Date:5/4/24

Write a C program to perform infix to postfix conversion using stack.

Algorithm:

```c
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>

struct node {
    char data;
    struct node* next;
};
struct node* top = NULL;
void push(char ele) {
    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = top;
        top = newnode;
    }
}

char pop() {
    if (top == NULL) { printf("\nStack
        Underflow\n"); return -1;
    } else {
        char popped = top->data;
        struct node* temp = top;
        top = top->next;
        free(temp);
        return popped;
    }
}

char peek() {
    if (top != NULL) {
        return top->data;
    } else {
        return -1;
    }
}

int isEmpty() {
    return top == NULL;
}
```

```c
int precedence(char op) {
    switch (op) {
        case '+':
        case '-': return 1;
        case '*':
        case '/': return 2;
        case '^': return 3;
        default: return 0;
    }
}
int isOperator(char ch) {
    return ch == '+' || ch == '-' || ch == '*' || ch == '/' || ch == '^';
}
void infixToPostfix(char* infix, char* postfix) {
    int i = 0, j = 0;
    while (infix[i] != '\0') {
        if (isdigit(infix[i]) || isalpha(infix[i])) {
            postfix[j++] = infix[i];
        } else if (infix[i] == '(') {
            push(infix[i]);
        } else if (infix[i] == ')') {
            while (!isEmpty() && peek() != '(') {
                postfix[j++] = pop();
            }
            pop(); // Remove '(' from stack
        } else if (isOperator(infix[i])) {
            while (!isEmpty() && precedence(peek()) >= precedence(infix[i])) {
                postfix[j++] = pop();
            }
            push(infix[i]);
        }
        i++;
    }
    while (!isEmpty()) {
        postfix[j++] = pop();
    }
    postfix[j] = '\0';
}
int main() {
    char infix[100] = "a+b*(c^d-e)^(f+g*h)-i";
    char postfix[100];

    printf("Infix expression: %s\n", infix);
    infixToPostfix(infix, postfix);
    printf("Postfix expression: %s\n", postfix);

    return 0;
}
```

Ex. No.: 6	Evaluating Arithmetic Expression	Date: 12/4/24

Write a C program to evaluate Arithmetic expression using stack.

Algorithm:

```c
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>

struct node {
    int data;
    struct node* next;
};
struct node* top = NULL;

void push(int ele) {

    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = top;
        top = newnode;
    }
}

int pop() {
    if (top == NULL) { printf("\nStack
        Underflow\n"); return -1;
    } else {
        int popped = top->data;
        struct node* temp = top;
        top = top->next;
        free(temp);
        return popped;
    }
}

int isEmpty() {
    return top == NULL;
}

int evaluatePostfix(char* expression) {
    int i = 0;
    while (expression[i] != '\0') {
        if (isdigit(expression[i])) {
```

```c
            push(expression[i] - '0');
        } else {
            int val1 = pop();
            int val2 = pop();
            switch (expression[i]) {
                case '+': push(val2 + val1); break;
                case '-': push(val2 - val1); break;
                case '*': push(val2 * val1); break;
                case '/': push(val2 / val1); break;
            }
        }
        i++;
    }
    return pop();
}

int main() {
    char postfix[100] = "53+62/*35*+";
    printf("Postfix expression: %s\n", postfix);
    int result = evaluatePostfix(postfix);
    printf("Evaluation result: %d\n", result);

    return 0;
}
```

Ex. No.: 7	Implementation of Queue using Array and Linked List Implementation	Date: 19/ 4/24

Write a C program to implement a Queue using Array and linked List implementation and execute the following operation on stack.

(i) **Enqueue**

(ii) **Dequeue**

(iii) **Display the elements in a Queue**

Algorithm:

```c
#include <stdio.h>
#include <stdlib.h>

struct node {
    int data;
    struct node* next;
};

struct node* head = NULL;
struct node* tail = NULL;

void enqueue(int ele) {
    struct node* newnode = (struct node*)malloc(sizeof(struct node));
    if (newnode != NULL) {
        newnode->data = ele;
        newnode->next = NULL;
        if (tail == NULL) {
            head = tail = newnode;
        } else {
            tail->next = newnode;
            tail = newnode;
        }
    }
}

int dequeue() {
    if (head == NULL) {
        printf("\nQueue Underflow\n");
        return -1;
    } else {
        int dequeued = head->data;
        struct node* temp = head;
        head = head->next;
        if (head == NULL) {
            tail = NULL;
        }
        free(temp);
        return dequeued;
```

```c
    }
}

int isEmpty() {
    return head == NULL;
}

void display() {
    struct node* t = head;
    while (t != NULL) {
        printf("%d\t", t->data);
        t = t->next;
    }
    printf("\n");
}

int main() {
    enqueue(10);
    enqueue(20);
    enqueue(30);
    display();

    printf("Dequeued element: %d\n", dequeue());
    display();

    printf("Dequeued element: %d\n", dequeue());
    display();
    printf("Is queue empty? %s\n", isEmpty() ? "Yes" : "No");

    enqueue(40);

    display();

    printf("Is queue empty? %s\n", isEmpty() ? "Yes" : "No");

    return 0;
}
```

| Ex. No.: 8 | **Tree Traversal** | Date: 17/5/24 |

Write a   C p r o g r a m t o i m p l e m e n t a B i n a r y t r e e a n d p e r f o r m t h e f o l l o w i n g t r e e t r a v e r s a l o p e r a t i o n .

(i)   **Inorder Traversal**

(ii)   **Preorder Traversal**

(iii)   **Postorder Traversal**

Algorithm:

```c
#include <stdio.h>
#include <malloc.h>
struct node {
    int data;
    struct node* left;
    struct node* right;
};
struct node* root = NULL;
struct node* newnode;

void insert(int ele) {
    newnode = (struct node*)malloc(sizeof(struct node));
    newnode->data = ele;
    newnode->left = newnode->right = NULL;

   if (root == NULL) {
        root = newnode;
    } else {
        struct node* current = root;
        struct node* parent = NULL;

        while (1) {
            parent = current;
            if (ele < parent->data) {
                current = current->left;
                if (current == NULL) {
                    parent->left = newnode;
                    return;
                }
            } else {
                current = current->right;
                if (current == NULL) {
                    parent->right = newnode;
                    return;
                }
            }
```

```c
        }
    }
}
void inorder(struct node* t) {
    if (root == NULL) return;
    if (t != NULL) {
        inorder(t->left);
        printf("%d ", t->data);
        inorder(t->right);
    }
}
void preorder(struct node* t) {
    if (root == NULL) return;
    if (t != NULL) {
        printf("%d ", t->data);
        preorder(t->left);
        preorder(t->right);
    }
}
void postorder(struct node* t) {
    if (root == NULL) return; if
    (t != NULL) {
        postorder(t->left);
        postorder(t->right);
        printf("%d ", t->data);
    }
}
int main() {
    insert(5);
    insert(3);
    insert(7);
    insert(2);
    insert(4);
    insert(6);
    insert(8);

    printf("Inorder Traversal: ");
    inorder(root);
    printf("\n");

    printf("Preorder Traversal: ");
    preorder(root);
    printf("\n");

    printf("Postorder Traversal: ");
    postorder(root);
    printf("\n");

    return 0;
}
```

Ex. No.: 9	Implementation of Binary Search tree	Date: 17/5/24

Write a C program to implement a Binary Search Tree and perform the following operations.

(i) **Insert**

(ii) **Delete**

(iii) **Search**

(iv) **Display**

Algorithm:

```c
#include <stdio.h>
#include <stdlib.h>
struct node {
    int data;
    struct node* left;
    struct node* right;
};
struct node* createNode(int data) {
    struct node* newNode = (struct node*)malloc(sizeof(struct node));
    if (newNode != NULL) {
        newNode->data = data;
        newNode->left = NULL;
        newNode->right = NULL;
    }
    return newNode;
}
struct node* insert(struct node* root, int data) {
    if (root == NULL) {
        return createNode(data);
    }
    if (data < root->data) {
        root->left = insert(root->left, data);
    } else if (data > root->data) {
        root->right = insert(root->right, data);
    }
    return root;
}
struct node* search(struct node* root, int data) {
    if (root == NULL || root->data == data) {
        return root;
    }
    if (data < root->data) {
        return search(root->left, data);
    }
    return search(root->right, data);
}
```

```c
struct node* findMin(struct node* root) {
    while (root->left != NULL) {
        root = root->left;
    }
    return root;
}
struct node* deleteNode(struct node* root, int data) {
    if (root == NULL) {
        return root;
    }
    if (data < root->data) {
        root->left = deleteNode(root->left, data);
    } else if (data > root->data) {
        root->right = deleteNode(root->right, data);
    } 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;
        }
        struct node* temp = findMin(root->right);
        root->data = temp->data;
        root->right = deleteNode(root->right, temp->data);
    }
    return root;
}
void inorder(struct node* root) {
    if (root != NULL) {
        inorder(root->left);
        printf("%d\t", root->data);
        inorder(root->right);
    }
}
void preorder(struct node* root) {
    if (root != NULL) {
        printf("%d\t", root->data);
        preorder(root->left);
        preorder(root->right);
    }
}
void postorder(struct node* root) {
    if (root != NULL) {
        postorder(root->left);
        postorder(root->right);
        printf("%d\t", root->data);
    }
```

```c
}
int main() {
    struct node* root = NULL;
    root = insert(root, 50);
    insert(root, 30);
    insert(root, 70);
    insert(root, 20);
    insert(root, 40);
    insert(root, 60);
    insert(root, 80);

    printf("Inorder traversal: ");
    inorder(root);
    printf("\n");

    printf("Preorder traversal: ");
    preorder(root);
    printf("\n");

    printf("Postorder traversal: ");
    postorder(root);
    printf("\n");

    int key = 40;
    if (search(root, key) != NULL) {
        printf("Element %d found in the BST\n", key);
    } else {
        printf("Element %d not found in the BST\n", key);
    }
    printf("Deleting 20\n");
    root = deleteNode(root, 20);
    printf("Inorder traversal after deletion: ");
    inorder(root);
    printf("\n");
    printf("Deleting 30\n");
    root = deleteNode(root, 30);
    printf("Inorder traversal after deletion: ");
    inorder(root);
    printf("\n");

    printf("Deleting 50\n");
    root = deleteNode(root, 50);
    printf("Inorder traversal after deletion: ");
    inorder(root);
    printf("\n");

    return 0;
}
```

Ex. No.: 10	Implementation of AVL Tree	Date: 24/5/24

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.

Algorithm:

```c
#include <stdio.h>
#include <malloc.h>

struct node {
    int data;
    struct node* left;
    struct node* right;
    int height;
};

struct node* root = NULL;
struct node* newnode;

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* rightRotate(struct node* y) {
    struct node* x = y->left;
    struct node* T2 = x->right;
    x->right = y;
    y->left = T2;
    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 ele) {
        if (node == NULL) {
            newnode = (struct node*)malloc(sizeof(struct node));
            newnode->data = ele;
            newnode->left = newnode->right = NULL;
            newnode->height = 1;
            return newnode;
        }
        if (ele < node->data) {
            node->left = insert(node->left, ele);
        } else if (ele > node->data) {
            node->right = insert(node->right, ele);
        } else {
            return node;
        }
        node->height = 1 + max(height(node->left), height(node->right));
        int balance = getBalance(node);

        if (balance > 1 && ele < node->left->data) return rightRotate(node);
        if (balance < -1 && ele > node->right->data) return leftRotate(node);
        if (balance > 1 && ele > node->left->data) {
            node->left = leftRotate(node->left);
            return rightRotate(node);
        }
        if (balance < -1 && ele < node->right->data) {
            node->right = rightRotate(node->right);
            return leftRotate(node);
        }
        return node;
    }

    void inorder(struct node* t) {
        if (root == NULL) return;
        if (t != NULL) {
            inorder(t->left);
            printf("%d ", t->data);
            inorder(t->right);
        }
    }

    void preorder(struct node* t) {
        if (root == NULL) return;
        if (t != NULL) {
```

```c
        printf("%d ", t->data);
        preorder(t->left);
        preorder(t->right);
    }
}

void postorder(struct node* t) {
    if (root == NULL) return; if
    (t != NULL) {
        postorder(t->left);
        postorder(t->right);
        printf("%d ", t->data);
    }
}

int main() {
    root = insert(root, 10);
    root = insert(root, 20);
    root = insert(root, 30);
    root = insert(root, 40);
    root = insert(root, 50);
    root = insert(root, 25);

    printf("Inorder Traversal: ");
    inorder(root);
    printf("\n");

    printf("Preorder Traversal: ");
    preorder(root);
    printf("\n");

    printf("Postorder Traversal: ");
    postorder(root);
    printf("\n");

    return 0;
}
```

Ex. No.: 11	**Graph Traversal**	Date: 24/5/24

Write a C program to create a graph and perform a Breadth First Search.

Algorithm:

```c
#include <stdio.h>
#include <stdlib.h>

struct node {
    int vertex; struct
    node* next;
};

struct adj_list {
    struct node* head;
};

struct graph {
    int num_vertices;
    struct adj_list* adj_lists;
    int* visited;
};

struct node* new_node(int vertex) {
    struct node* new_node = (struct node*)malloc(sizeof(struct node));
    new_node->vertex = vertex;
    new_node->next = NULL;
    return new_node;
}

struct graph* create_graph(int n) {
    struct graph* graph = (struct graph*)malloc(sizeof(struct graph));
    graph->num_vertices = n;
    graph->adj_lists = (struct adj_list*)malloc(n * sizeof(struct adj_list));
    graph->visited = (int*)malloc(n * sizeof(int));
    for (int i = 0; i < n; i++) {
        graph->adj_lists[i].head = NULL;
        graph->visited[i] = 0;
    }
    return graph;
}

void add_edge(struct graph* graph, int src, int dest) {
    struct node* new_node1 = new_node(dest);
    new_node1->next = graph->adj_lists[src].head;
    graph->adj_lists[src].head = new_node1;

    struct node* new_node2 = new_node(src);
```

```c
    new_node2->next = graph->adj_lists[dest].head;
    graph->adj_lists[dest].head = new_node2;
}

void bfs(struct graph* graph, int v) {
    int queue[1000];
    int front = -1;
    int rear = -1;
    graph->visited[v] = 1;
    queue[++rear] = v;
    while (front != rear) {
        int current_vertex = queue[++front];
        printf("%d ", current_vertex);
        struct node* temp = graph->adj_lists[current_vertex].head;
        while (temp != NULL) {
            int adj_vertex = temp->vertex;
            if (graph->visited[adj_vertex] == 0) {
                graph->visited[adj_vertex] = 1;
                queue[++rear] = adj_vertex;
            }
            temp = temp->next;
        }
    }
}

int main() {
    struct graph* graph = create_graph(6);
    add_edge(graph, 0, 1);
    add_edge(graph, 0, 2);
    add_edge(graph, 1, 3);
    add_edge(graph, 1, 4);
    add_edge(graph, 2, 4);
    add_edge(graph, 3, 4);
    add_edge(graph, 3, 5);
    add_edge(graph, 4, 5);
    printf("BFS traversal starting from vertex 0: ");
    bfs(graph, 0);
    return 0;
}
```

| Ex. No.: 11 | **Graph Traversal** | Date: 24/5/24 |

Write a C program to create a graph and perform a Depth First Search.

Algorithm:

```c
#include <stdio.h>
#include <stdlib.h>

int vis[100];

struct Graph {
    int V;
    int E;
    int** Adj;
};

struct Graph* adjMatrix() {
    struct Graph* G = (struct Graph*)malloc(sizeof(struct Graph));
    if (!G) {
        printf("Memory Error\n");
        return NULL;
    }
    G->V = 7;
    G->E = 7;
    G->Adj = (int**)malloc((G->V) * sizeof(int*));
    for (int k = 0; k < G->V; k++) {
        G->Adj[k] = (int*)malloc((G->V) * sizeof(int));
    }
    for (int u = 0; u < G->V; u++) { for
        (int v = 0; v < G->V; v++) {
            G->Adj[u][v] = 0;
        }
    }
    G->Adj[0][1] = G->Adj[1][0] = 1;
    G->Adj[0][2] = G->Adj[2][0] = 1;
    G->Adj[1][3] = G->Adj[3][1] = 1;
    G->Adj[1][4] = G->Adj[4][1] = 1;
    G->Adj[1][5] = G->Adj[5][1] = 1;
    G->Adj[1][6] = G->Adj[6][1] = 1;
    G->Adj[6][2] = G->Adj[2][6] = 1;
    return G;
}

void DFS(struct Graph* G, int u) {
    vis[u] = 1;
    printf("%d ", u);
    for (int v = 0; v < G->V; v++) {
```

```
        if (!vis[v] && G->Adj[u][v]) {
            DFS(G, v);
        }
    }
}

void DFStraversal(struct Graph* G) {
    for (int i = 0; i < 100; i++) {
        vis[i] = 0;
    }
    for (int i = 0; i < G->V; i++) {
        if (!vis[i]) {
            DFS(G, i);
        }
    }
}

void main() {
    struct Graph* G;
    G = adjMatrix();
    DFStraversal(G);
}
```

Ex. No.: 12	**Topological Sorting**	Date: 24/5/24

Write a C program to create a graph and display the ordering of vertices.

Algorithm:

```c
#include <stdio.h>
#include <malloc.h>

struct node {
    int vertex; struct
    node* next;
};

struct Graph {
    int numVertices; struct
    node** adjLists; int*
    visited;
};

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;
}

void topologicalSortUtil(int v, struct Graph* graph, int* stack, int* stackIndex) {
    graph->visited[v] = 1;
```

```c
        struct node* adjList = graph->adjLists[v];
        struct node* temp = adjList;

        while (temp != NULL) {
            int connectedVertex = temp->vertex;
            if (!graph->visited[connectedVertex]) {
                topologicalSortUtil(connectedVertex, graph, stack, stackIndex);
            }
            temp = temp->next;
        }

        stack[(*stackIndex)++] = v;
    }

    void topologicalSort(struct Graph* graph) {
        int* stack = (int*)malloc(graph->numVertices * sizeof(int));
        int stackIndex = 0;

        for (int i = 0; i < graph->numVertices; i++) {
            if (graph->visited[i] == 0) {
                topologicalSortUtil(i, graph, stack, &stackIndex);
            }
        }

        for (int i = stackIndex - 1; i >= 0; i--) {
            printf("%d ", stack[i]);
        }
        free(stack);
    }

    int main() {
        struct Graph* graph = createGraph(6);
        addEdge(graph, 5, 2);
        addEdge(graph, 5, 0);
        addEdge(graph, 4, 0);
        addEdge(graph, 4, 1);
        addEdge(graph, 2, 3);
        addEdge(graph, 3, 1);

        printf("Topological Sort: ");
        topologicalSort(graph);
        printf("\n");

        return 0;
    }
```

Ex. No.: 13	**Graph Traversal**	Date: 31/5/24

Write a C program to create a graph and find a minimum spanning tree using prims algorithm.

Algorithm:

```c
#include <stdio.h>
#include <limits.h>

#define MAX_VERTICES 100

int minKey(int key[], int mstSet[], int vertices) {
    int min = INT_MAX, minIndex;
    for (int v = 0; v < vertices; v++) {
        if (!mstSet[v] && key[v] < min) {
            min = key[v];
            minIndex = v;
        }
    }
    return minIndex;
}

void printMST(int parent[], int graph[MAX_VERTICES][MAX_VERTICES], int vertices) {
    printf("Edge \tWeight\n");
    for (int i = 1; i < vertices; i++) {
        printf("%d - %d \t%d\n", parent[i], i, graph[i][parent[i]]);
    }
}

void primMST(int graph[MAX_VERTICES][MAX_VERTICES], int vertices) {
    int parent[MAX_VERTICES];
    int key[MAX_VERTICES];
    int mstSet[MAX_VERTICES];

    for (int i = 0; i < vertices; i++) {
        key[i] = INT_MAX;
        mstSet[i] = 0;
    }

    key[0] = 0;
    parent[0] = -1;

    for (int count = 0; count < vertices - 1; count++) {
        int u = minKey(key, mstSet, vertices);

        mstSet[u] = 1;

        for (int v = 0; v < vertices; v++) {
```

```c
            if (graph[u][v] && !mstSet[v] && graph[u][v] < key[v]) {
                parent[v] = u;
                key[v] = graph[u][v];
            }
        }
    }

    printMST(parent, graph, vertices);
}

int main() {
    int vertices;
    printf("Input the number of vertices: ");
    scanf("%d", &vertices);

    if (vertices <= 0 || vertices > MAX_VERTICES) {
        printf("Invalid number of vertices. Exiting...\n");
        return 1;
    }

    int graph[MAX_VERTICES][MAX_VERTICES];

    printf("Input the adjacency matrix for the graph:\n");
    for (int i = 0; i < vertices; i++) {
        for (int j = 0; j < vertices; j++) {
            scanf("%d", &graph[i][j]);
        }
    }

    primMST(graph, vertices);
    return 0;
}
```

| Ex. No.: 14 | **Graph Traversal** | Date: 31/5/24 |

Write a C program to create a graph and find the shortest path using Dijikstra's Algorithm.

Algorithm:

```c
#include <stdio.h>
#include <limits.h>

#define MAX_VERTICES 100

int minDistance(int dist[], int sptSet[], int vertices) {
    int min = INT_MAX, minIndex;
    for (int v = 0; v < vertices; v++) {
        if (!sptSet[v] && dist[v] < min) {
            min = dist[v];
            minIndex = v;
        }
    }
    return minIndex;
}

void printSolution(int dist[], int vertices) {
    printf("Vertex \tDistance from Source\n");
    for (int i = 0; i < vertices; i++) {
        printf("%d \t%d\n", i, dist[i]);
    }
}

void dijkstra(int graph[MAX_VERTICES][MAX_VERTICES], int src, int vertices) {
    int dist[MAX_VERTICES];
    int sptSet[MAX_VERTICES];

    for (int i = 0; i < vertices; i++) {
        dist[i] = INT_MAX;
        sptSet[i] = 0;
    }

    dist[src] = 0;

    for (int count = 0; count < vertices - 1; count++) {
        int u = minDistance(dist, sptSet, vertices);
        sptSet[u] = 1;

        for (int v = 0; v < vertices; v++) {
            if (!sptSet[v] && graph[u][v] && dist[u] != INT_MAX && dist[u] +
graph[u][v] < dist[v]) {
                dist[v] = dist[u] + graph[u][v];
```

```c
            }
        }
    }

    printSolution(dist, vertices);
}

int main() {
    int vertices;
    printf("Input the number of vertices: ");
    scanf("%d", &vertices);

    if (vertices <= 0 || vertices > MAX_VERTICES) {
        printf("Invalid number of vertices. Exiting...\n");
        return 1;
    }

    int graph[MAX_VERTICES][MAX_VERTICES];

    printf("Input the adjacency matrix for the graph (use INT_MAX for
infinity):\n");
    for (int i = 0; i < vertices; i++) {
        for (int j = 0; j < vertices; j++) {
            scanf("%d", &graph[i][j]);
        }
    }

    int source;
    printf("Input the source vertex: ");
    scanf("%d", &source);

    if (source < 0 || source >= vertices) {
        printf("Invalid source vertex. Exiting...\n");
        return 1;
    }

    dijkstra(graph, source, vertices);
    return 0;
}
```

Ex. No.: 15	**Sorting**	Date: 31/5/24

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**

Code :

```c
#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;
}

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 arr[] = { 19, 17, 15, 12, 16, 18, 4, 11, 13 };
    int n = sizeof(arr) / sizeof(arr[0]);
```

```c
    printf("Original array: ");
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }

    quickSort(arr, 0, n - 1);

    printf("\nSorted array: ");
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }

    return 0;
}
```

2.Merge Sort

```c
#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++;
    }
    while (i < n1) {
        arr[k] = L[i];
```

```c
        i++;
        k++;
    }
    while (j < n2) {
        arr[k] = R[j];
        j++;
        k++;
    }
}

void mergeSort(int arr[], int l, int r) {
    if (l < r) {
        int m = l + (r - l) / 2;
        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");
}

int main() {
    int arr[] = { 12, 11, 13, 5, 6, 7 };
    int arr_size = sizeof(arr) / sizeof(arr[0]);
    printf("Given array is \n"); printArray(arr,
    arr_size);
    mergeSort(arr, 0, arr_size - 1);
    printf("\nSorted array is \n");
    printArray(arr, arr_size);
    return 0;
}
```

Ex. No.: 16	**Hashing**	Date: 31/5/24

Write a   C p r o g r a m t o c r e a t e   a   h a s h t a b l e a n d p e r f o r m c o l l i s i o n r e s o l u t i o n u s i n g t h e f o l l o w i n g t e c h n i q u e s.

(i)   O p e n a d d r e s s i n g

(ii)   C l o s e d A d d r e s s i n g

(iii)   R e h a s h i n

g Algorithm:

```c
#include <stdio.h>
#include <stdlib.h>
#include <stdbool.h>

typedef struct HashTable {
    int size;
    int count; // Number of elements in the table
    int* keys;
    int* values;
    bool* isOccupied; // Indicates if a slot is occupied
} HashTable;

HashTable* createTable(int size) {
    HashTable* newTable = (HashTable*)malloc(sizeof(HashTable));
    newTable->size = size;
    newTable->count = 0;
    newTable->keys = (int*)malloc(sizeof(int) * size);
    newTable->values = (int*)malloc(sizeof(int) * size);
    newTable->isOccupied = (bool*)malloc(sizeof(bool) * size);
    for (int i = 0; i < size; i++) {
        newTable->isOccupied[i] = false;
    }
    return newTable;
}

int hashFunction(int key, int size) {
    return key % size;
}

void rehash(HashTable* hashTable);

void insert(HashTable* hashTable, int key, int value) {
    if ((float)hashTable->count / hashTable->size >= 0.75) {
        rehash(hashTable);
    }
```

```
    int hashIndex = hashFunction(key, hashTable->size);
    int originalIndex = hashIndex;
    int i = 1;

    while (hashTable->isOccupied[hashIndex]) {
        if (hashTable->keys[hashIndex] == key) {
            // If the key already exists, update the value
            hashTable->values[hashIndex] = value;
            return;
        }
        // Linear probing
        hashIndex = (originalIndex + i) % hashTable->size;
        i++;
    }

    hashTable->keys[hashIndex] = key;
    hashTable->values[hashIndex] = value;
    hashTable->isOccupied[hashIndex] = true;
    hashTable->count++;
}

void rehash(HashTable* hashTable) {
    int oldSize = hashTable->size;
    int* oldKeys = hashTable->keys;
    int* oldValues = hashTable->values;
    bool* oldIsOccupied = hashTable->isOccupied;

    int newSize = oldSize * 2;
    hashTable->keys = (int*)malloc(sizeof(int) * newSize);
    hashTable->values = (int*)malloc(sizeof(int) * newSize);
    hashTable->isOccupied = (bool*)malloc(sizeof(bool) * newSize);
    hashTable->size = newSize;
    hashTable->count = 0;

    for (int i = 0; i < newSize; i++) {
        hashTable->isOccupied[i] = false;
    }

    for (int i = 0; i < oldSize; i++) {
        if (oldIsOccupied[i]) {
            insert(hashTable, oldKeys[i], oldValues[i]);
        }
    }

    free(oldKeys);
    free(oldValues);
    free(oldIsOccupied);
}

int search(HashTable* hashTable, int key) {
```

```c
    int hashIndex = hashFunction(key, hashTable->size);
    int originalIndex = hashIndex;
    int i = 1;

    while (hashTable->isOccupied[hashIndex]) {
        if (hashTable->keys[hashIndex] == key) {
            return hashTable->values[hashIndex];
        }
        // Linear probing
        hashIndex = (originalIndex + i) % hashTable->size;
        i++;
        if (hashIndex == originalIndex) {
            break; // We have circled back to the original index
        }
    }
    return -1; // Key not found
}

void delete(HashTable* hashTable, int key) {
    int hashIndex = hashFunction(key, hashTable->size);
    int originalIndex = hashIndex;
    int i = 1;

    while (hashTable->isOccupied[hashIndex]) {
        if (hashTable->keys[hashIndex] == key) {
            hashTable->isOccupied[hashIndex] = false;
            hashTable->count--;
            return;
        }
        // Linear probing
        hashIndex = (originalIndex + i) % hashTable->size;
        i++;
        if (hashIndex == originalIndex) {
            break; // We have circled back to the original index
        }
    }
}

void freeTable(HashTable* hashTable) {
    free(hashTable->keys);
    free(hashTable->values);
    free(hashTable->isOccupied);
    free(hashTable);
}

int main() {
    HashTable* hashTable = createTable(5);
    insert(hashTable, 1, 10);
    insert(hashTable, 2, 20);
    insert(hashTable, 3, 30);
```

```
    insert(hashTable, 4, 40);
    insert(hashTable, 5, 50);
    insert(hashTable, 6, 60); // This should trigger rehashing
    printf("Value for key 1: %d\n", search(hashTable, 1));
    printf("Value for key 2: %d\n", search(hashTable, 2));
    printf("Value for key 3: %d\n", search(hashTable, 3));
    printf("Value for key 4: %d\n", search(hashTable, 4));
    printf("Value for key 5: %d\n", search(hashTable, 5));
    printf("Value for key 6: %d\n", search(hashTable, 6));
    delete(hashTable, 3);
    printf("Value for key 3 after deletion: %d\n", search(hashTable, 3));
    freeTable(hashTable);
    return 0;
}
```

2.CLOSED ADDRESSING

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

typedef struct Node {
    int key;
    int value;
    struct Node* next;
} Node;

typedef struct HashTable {
    int size;
    Node** table;
} HashTable;

Node* createNode(int key, int value) {
    Node* newNode = (Node*)malloc(sizeof(Node));
    newNode->key = key;
    newNode->value = value;
    newNode->next = NULL;
    return newNode;
}

HashTable* createTable(int size) {
    HashTable* newTable = (HashTable*)malloc(sizeof(HashTable));
    newTable->size = size;
    newTable->table = (Node**)malloc(sizeof(Node*) * size);
    for (int i = 0; i < size; i++) {
        newTable->table[i] = NULL;
    }
    return newTable;
}
```

```c
int hashFunction(int key, int size) {
    return key % size;
}

void insert(HashTable* hashTable, int key, int value) {
    int hashIndex = hashFunction(key, hashTable->size);
    Node* newNode = createNode(key, value);
    newNode->next = hashTable->table[hashIndex];
    hashTable->table[hashIndex] = newNode;
}

int search(HashTable* hashTable, int key) {
    int hashIndex = hashFunction(key, hashTable->size);
    Node* current = hashTable->table[hashIndex];
    while (current != NULL) {
        if (current->key == key) {
            return current->value;
        }
        current = current->next;
    }
    return -1;
}

void delete(HashTable* hashTable, int key) {
    int hashIndex = hashFunction(key, hashTable->size);
    Node* current = hashTable->table[hashIndex];
    Node* prev = NULL;
    while (current != NULL && current->key != key) {
        prev = current;
        current = current->next;
    }
    if (current == NULL) {
        return;
    }
    if (prev == NULL) {
        hashTable->table[hashIndex] = current->next;
    } else {
        prev->next = current->next;
    }
    free(current);
}

void freeTable(HashTable* hashTable) {
    for (int i = 0; i < hashTable->size; i++) {
        Node* current = hashTable->table[i];
        while (current != NULL) {
            Node* temp = current;
            current = current->next;
            free(temp);
```

```c
        }
    }
    free(hashTable->table);
    free(hashTable);
}

int main() {
    HashTable* hashTable = createTable(10);
    insert(hashTable, 1, 10);
    insert(hashTable, 2, 20);
    insert(hashTable, 12, 30);
    printf("Value for key 1: %d\n", search(hashTable, 1));
    printf("Value for key 2: %d\n", search(hashTable, 2));
    printf("Value for key 12: %d\n", search(hashTable, 12));
    printf("Value for key 3: %d\n", search(hashTable, 3)); // Key not present
    delete(hashTable, 2);
    printf("Value for key 2 after deletion: %d\n", search(hashTable, 2));
    freeTable(hashTable);
    return 0;
}
```

C) REHASHING

```c
#include <stdio.h>
#include <stdlib.h>

typedef struct Node {
    int key;
    int value;
    struct Node* next;
} Node;

typedef struct HashTable {
    int size;
    int count; // Number of elements in the table
    Node** table;
} HashTable;

Node* createNode(int key, int value) {
    Node* newNode = (Node*)malloc(sizeof(Node));
    newNode->key = key;
    newNode->value = value;
    newNode->next = NULL;
    return newNode;
}

HashTable* createTable(int size) {
    HashTable* newTable = (HashTable*)malloc(sizeof(HashTable));
    newTable->size = size;
```

```c
    newTable->count = 0;
    newTable->table = (Node**)malloc(sizeof(Node*) * size);
    for (int i = 0; i < size; i++) {
        newTable->table[i] = NULL;
    }
    return newTable;
}

int hashFunction(int key, int size) {
    return key % size;
}

void insert(HashTable* hashTable, int key, int value);
void rehash(HashTable* hashTable) {
    int oldSize = hashTable->size;
    Node** oldTable = hashTable->table;
    int newSize = oldSize * 2;
    hashTable->table = (Node**)malloc(sizeof(Node*) * newSize);
    hashTable->size = newSize;
    hashTable->count = 0;
    for (int i = 0; i < newSize; i++) {
        hashTable->table[i] = NULL;
    }
    for (int i = 0; i < oldSize; i++) {
        Node* current = oldTable[i];
        while (current != NULL) {
            insert(hashTable, current->key, current->value);
            Node* temp = current;
            current = current->next;
            free(temp);
        }
    }
    free(oldTable);
}

void insert(HashTable* hashTable, int key, int value) {
    if ((float)hashTable->count / hashTable->size >= 0.75) {
        rehash(hashTable);
    }
    int hashIndex = hashFunction(key, hashTable->size);
    Node* newNode = createNode(key, value);
    newNode->next = hashTable->table[hashIndex];
    hashTable->table[hashIndex] = newNode;
    hashTable->count++;
}

int search(HashTable* hashTable, int key) {
    int hashIndex = hashFunction(key, hashTable->size);
    Node* current = hashTable->table[hashIndex];
    while (current != NULL) {
```

```c
        if (current->key == key) {
            return current->value;
        }
        current = current->next;
    }
    return -1;
}

void delete(HashTable* hashTable, int key) {
    int hashIndex = hashFunction(key, hashTable->size);
    Node* current = hashTable->table[hashIndex];
    Node* prev = NULL;
    while (current != NULL && current->key != key) {
        prev = current;
        current = current->next;
    }
    if (current == NULL) {
        return;
    }
    if (prev == NULL) {
        hashTable->table[hashIndex] = current->next;
    } else {
        prev->next = current->next;
    }
    free(current);
    hashTable->count--;
}

void freeTable(HashTable* hashTable) {
    for (int i = 0; i < hashTable->size; i++) {
        Node* current = hashTable->table[i];
        while (current != NULL) {
            Node* temp = current;
            current = current->next;
            free(temp);
        }
    }
    free(hashTable->table);
    free(hashTable);
}

int main() {
    HashTable* hashTable = createTable(5);
    insert(hashTable, 1, 10);
    insert(hashTable, 2, 20);
    insert(hashTable, 3, 30);
    insert(hashTable, 4, 40);
    insert(hashTable, 5, 50);
    insert(hashTable, 6, 60); // This should trigger rehashing
    printf("Value for key 1: %d\n", search(hashTable, 1));
```

```
    printf("Value for key 2: %d\n", search(hashTable, 2));
    printf("Value for key 3: %d\n", search(hashTable, 3));
    printf("Value for key 4: %d\n", search(hashTable, 4));
    printf("Value for key 5: %d\n", search(hashTable, 5));
    printf("Value for key 6: %d\n", search(hashTable, 6));
    delete(hashTable, 3);
    printf("Value for key 3 after deletion: %d\n", search(hashTable, 3));
    freeTable(hashTable);
    return 0;
}
```