MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Unit of MAHE, Manipal

DEPARTMENT OF INFORMATION & COMMUNICATION TECHNOLOGY

CERTIFICATE

This is to certify that Ms./Mr. ……...…… Reg. No. …..…… Section: …… Roll No: ……... has satisfactorily completed the lab exercises prescribed for Data Structures Lab [ICT 2141] of Second Year B. Tech. (IT/CCE) Degree at MIT, Manipal, in the academic year 2023-2024.

Date: …….....

Signature of the faculty

CONTENTS

Course Objectives

- Learn to implement some useful data structures
- To strengthen the ability to identify and apply suitable data structure for the given real-world problem.
- Learn to implement sorting and searching techniques.

Course Outcomes

At the end of this course, students will be able to

- Demonstrate proficiency in using basic data types and data structures using a suitable programming language.
- Implement the various data structures using a suitable programming language.
- Solve real-world applications using appropriate data structures.

Evaluation plan

Split up of 60 marks for Regular Lab Evaluation
Regular evaluations will be carried out and the split up will be as follows: Record: 16 Marks Lab Test: 20 Marks Quiz: 14 Marks Program Check = 10 Marks Total Internal Marks: = 60 Marks
End Semester Lab evaluation: 40 marks (Duration 2 hrs)
Program Write up: 15 Marks Program Execution: 25 Marks Total: 15+25 =40 Marks

INSTRUCTIONS TO THE STUDENTS

Pre- Lab Session Instructions

1. Students should carry the Lab Manual Book and the required stationary to every lab session
2. Be on time and follow the institution dress code
3. Must Sign in the log register provided
4. Make sure to occupy the allotted seat and answer the attendance
5. Adhere to the rules and maintain the decorum

In- Lab Session Instructions

- Follow the instructions on the allotted exercises
- Show the program and results to the instructors on completion of experiments
- On receiving approval from the instructor, copy the program and results in the Lab record
- Prescribed textbooks and class notes can be kept ready for reference if required

General Instructions for the exercises in Lab

- Implement the given exercise individually and not in a group.
- The programs should meet the following criteria:
    - Programs should be interactive with appropriate prompt messages, error messages if any, and descriptive messages for outputs.
    - Programs should perform input validation (Data type, range error, etc.) and give appropriate error messages and suggest corrective actions.
    - Comments should be used to give the statement of the problem and every function should indicate the purpose of the function, inputs and outputs.
    - Statements within the program should be properly indented.
    - Use meaningful names for variables and functions.
    - Make use of constants and type definitions wherever needed.
- Plagiarism (copying from others) is strictly prohibited and would invite severe penalty in evaluation.
- The exercises for each week are divided under three sets:
    - Solved exercise
    - Lab exercises - to be completed during lab hours

- Additional Exercises - to be completed outside the lab or in the lab to enhance the skill

- In case a student misses a lab class, he/ she must ensure that the experiment is completed during the repetition class with the permission of the faculty concerned but credit will be given only to one day's experiment(s).
- Students missing out lab on genuine reasons like conference, sport or activities assigned by the department or institute will have to take **prior permission** from the HOD to attend **additional lab** (with other batch) and complete it **before** the student goes on leave. The student could be awarded marks for the write up for that day provided he submits it during the **immediate** next lab.
- Students who fall sick should get permission from the HOD for evaluating the lab records. However, the attendance will not be given for that lab.
- Students will be evaluated only by the faculty with whom they are registered even though they carry out additional experiment in other batch.
- Presence of the student during the lab end semester exams is mandatory even if the student assumes he has scored enough to pass the examination
- Minimum attendance of 75% is mandatory to write the final exam.
- If the student loses his book, he/she will have to rewrite all the lab details in the lab record.
- Questions for lab tests and examination are not necessarily limited to the questions in the manual, but may involve some variations and/or combinations of the questions.
- A sample note preparation is given as a model for observation.

THE STUDENTS SHOULD NOT

- Bring mobile phones or any other electronic gadgets to the lab.
- Go out of the lab without permission.

SAMPLE LAB OBSERVATION NOTE PREPARATION USING C EDITOR

Introduction

This lab course introduces computer programming using the C language. In this lab, the student will be able to write, see and debug their first program.

Running a sample C program

Let's look at C program implementation in steps by writing, storing, compiling, and executing a sample program.

- Create a directory with section followed by roll number (to be unique); e.g. A21.
- As per the instructions given by the lab teacher, create *InchToCm.c* program.
    - Open a new notepad file and type the given program
- Save the file with name and extension as "*InchToCm.c*" into the respective directory created.

Sample Program (*InchToCm.c*)**:**

```
// InchToCm.c
// this program inputs a real number inches and outputs its centimeter equivalent
// (also a real number)
#include <iostream>
void main() // int main()
{
        float centimeters, inches;
        printf( "This program converts inches to centimeters \n");
        printf( "Enter a number ");
        scanf("%d",&inches);
        centimeters = inches * 2.54;
        printf("%f inches is equivalent to %f centimeters", inches, centimeters);
getch(); // return 0;
} // end main
```

- Run the program as per the instructions given by the lab teacher.
    - Compile the saved program and run it either by using keyboard short cuts or through the menu.

PROGRAM STRUCTURE AND PARTS

Comments

The first line of the file is:

// InchToCm

This line is a comment. Let's add a comment above the name of the program that contains the student's name.

- Edit the file. **Add the student's name on the top line** so that the first two lines of the file now look like:

// student's name

// InchToCm

Comments informs the people what the program/line is intended to do. The compiler ignores these lines.

Preprocessor Directives

After the initial comments, the student should be able to see the following line:

#include <iostream>

This is called a preprocessor directive. It tells the compiler to do something. Preprocessor directives always start with a # sign. In this case, the preprocessor directive includes the information in the file in stream as part of the program. Most of the programs will almost always have at least one include file. These header files are stored in a library that shall be learnt more in the subsequent labs.

The function main ()

The next non-blank line *void* ***main*** *()*specifies the name of a function as **main**. There must be exactly one function named *main* in each C program and this is where program execution starts. The *void* before *main ()* indicates the function is not returning any value and also to indicate empty argument list to the function. Essentially functions are units of C code that do a particular task. Large programs will have many functions just as large organizations have many functions. Small programs, like smaller organizations, have

fewer functions. The parentheses following the words *void main* contains a list of arguments to the function. In the present case, there is no *argument*. Arguments to functions indicate to the function what objects are provided to the function to perform any task. The curly braces ({) on the next line and on the last line (})of the program determine the beginning and ending of the function.

Variable Declarations

The line after the opening curly brace, *float centimeters, inches;* is called a variable declaration. This line tells the compiler to reserve two places in memory with adequate size for a real number (the *float* keyword indicates the variable as a real number). The memory locations will have the names *inches* and *centimeters* associated with them. The programs often have many different variables of many different types.

EXECUTABLE STATEMENTS

Output and Input

The statements following the variable declaration up to the closing curly brace are executable statements. The executable statements are statements that will be executed when the program run. *cout*, the output stream operator (<<) tells the compiler to generate instructions that will display information on the screen when the program run, and *cin*, the input stream operator (>>) reads information from the keyboard when the program run.

Assignment Statements

The statement *centimeters = inches * 2.54;* is an assignment statement. It calculates what is on the right hand side of the equation (in this case *inches * 2.54*) and stores it in the memory location that has the name specified on the left hand side of the equation (in this case, *centimeters*). So *centimeters = inches * 2.54* takes whatever was read into the memory location *inches*, multiplies it by 2.54, and stores the result in *centimeters*. The next statement outputs the result of the calculation.

Return Statement

The last statement of this program, *return 0;* returns the program control back to the operating system. The value 0 indicates that the program ended normally. The last line of

every main function written should be **return 0**; for **int main()**; this is indicated alternatively to **void main()** which may have a simple **return** statement

Syntax

Syntax is the way that a language must be phrased in order for it to be understandable. The general form of a C program is given below:

```
// program name
// other comments like what program does and student's name
# include <appropriate files>
void main()
{
Variable declarations;
Executable statements:
} // end main
```

LAB NO: 1 **Date:**

BASIC SEARCHING AND SORTING METHODS

Objectives:

In this lab, student will be able to:

1. Write C programs for basic searching and sorting techniques.

Lab exercises:

1. Write a program to search a given element in a list using
   i.) Linear Search
   ii.) Binary Search
2. Write a program to sort a given list of elements. Write the user defined functions to sort using:
   i.) Bubble Sort
   ii.) Selection Sort
   iii.) Insertion Sort

Additional Exercise:

1. Write a C program to read two matrices A & B, create and display a third matrix C such that C (i, j) = max (A(i, j) , B(i, j))
2. Write a recursive C program to
   i.) Search an element using Binary search technique.
   ii.) Sort an array using selection sort technique.
   iii.) Multiply two numbers using repeated addition
3. Write a program in C to read two matrices A & B and perform the following:
   i.) Multiply two matrices
   ii.) Add two matrices
   iii.) Read a square matrix and check if it a magic square or not.

LAB NO: 2 **Date:**

STRINGS AND CLASS CONCEPTS

Objectives:

In this lab students should be able to:

- Understand the basics of strings.
- Write and execute the programs using class concept.

Introduction to Strings and Structures:

Strings:

- A string is an array of characters. Any group of characters (except double quote sign) defined between double quotations is a constant string.
- Character strings are often used to build meaningful and readable programs.

The common operations performed on strings are

- Reading and writing strings
- Combining strings together
- Copying one string to another
- Comparing strings with one another
- Extracting a portion of a string

Declaration:

Syntax: *char* string_name[size];

- The size determines the number of characters in the string_name.

Structures:

In C, a structure is a user-defined data type that allows you to combine different variables of different data types into a single unit. It is used to group related data together so that it can be treated as a single entity. A structure is a composite data type, meaning it can hold multiple values of various types.

The basic syntax of defining a structure in C is as follows:

```
struct structure_name {
    data_type member1;
    data_type member2;
    // ... more members ...
};
```

A brief explanation of the elements:

struct: This keyword is used to define a structure.

structure_name: It is the name given to the structure, which is used to declare variables of that structure type.

data_type: Each member of the structure has its own data type, and it can be any valid C data type like int, float, char, or even another structure.

member1, member2, etc.: These are the names of the individual members (variables) that compose the structure.

Here's an example of a simple structure in C:

```
#include <stdio.h>

// Defining the structure
struct Person {
    char name[50];
    int age;
    float height;
};

int main() {
```

```
    // Declaring and initializing a variable of the "Person" structure
    struct Person person1 = {"John Doe", 30, 1.75};

    // Accessing the members of the structure using the dot (.) operator
    printf("Name: %s\n", person1.name);
    printf("Age: %d\n", person1.age);
    printf("Height: %.2f meters\n", person1.height);

    return 0;
}
```

In this example, we created a structure named Person that holds information about a person's name, age, and height. Then, we declared and initialized a variable person1 of type Person and accessed its members using the dot operator (.).

Structures are useful for organizing and managing data in a more meaningful and structured way, especially when dealing with complex data that involves multiple properties.

In C, you can use structures along with functions to encapsulate related data and operations on that data into a single entity. Functions that are associated with structures are commonly referred to as "structure member functions" or "methods" (though C does not have a native concept of methods like in object-oriented languages).

To work with functions and structures together, you can define functions that operate on the data members of the structure. Here's an example demonstrating how to create a structure with functions:

```
#include <stdio.h>

// Define the structure
struct Rectangle {
    int length;
    int width;
};

// Function to calculate the area of a rectangle
```

```
int calculateArea(struct Rectangle rect) {
    return rect.length * rect.width;
}

// Function to calculate the perimeter of a rectangle
int calculatePerimeter(struct Rectangle rect) {
    return 2 * (rect.length + rect.width);
}

int main() {
    // Declare and initialize a variable of the "Rectangle" structure
    struct Rectangle myRectangle = {5, 10};

    // Call the functions associated with the structure
    int area = calculateArea(myRectangle);
    int perimeter = calculatePerimeter(myRectangle);

    // Display the results
    printf("Rectangle area: %d\n", area);
    printf("Rectangle perimeter: %d\n", perimeter);

    return 0;
}
```

In this example, we created a structure named Rectangle, which represents a rectangle with length and width as its data members. We then defined two functions, calculateArea and calculatePerimeter, which take a Rectangle structure as an argument and return the area and perimeter of the rectangle, respectively.

By encapsulating these functions within the structure, you can easily perform operations on the structure's data without having to pass each member individually as function arguments. It also helps in organizing the code and makes it more maintainable.

Keep in mind that in C, structures do not inherently support the concept of private or public members like in some other programming languages, and direct access to structure

members from outside the structure is possible. However, it's a good practice to keep the structure members private and provide functions to access or modify them, which is often referred to as encapsulation. This way, you can control the access and manipulation of the data in a structured manner. Note that in C++, you have access control keywords like private and public to better enforce encapsulation.

Solved exercise

Code snippet to read a string

```
#include <stdio.h>
int main() {
   char str[100];
   printf("Enter a string: ");
   scanf(" %[^\n]", str);
   printf("String read: %s\n", str);
   return 0;
}
```

Lab exercises

1. Write a program to perform following string operations without using string handling functions:
   a.) length of the string
   b.) string concatenation
   c.) string comparison
   d.) to insert a sub string
   e.) to delete a substring
2. Write a C program to define a structure **student** with the data members to store name, roll no and grade of the student. Also write the member functions to read, display, and sort student information according to the roll number of the student. All the member functions will have array of objects as arguments.
3. Define a structure **time** with data members hour, min, sec. Write the user defined functions to (i) Add (ii) To find difference between two objects of class time. Functions take two-time objects as argument and return time object. Also write the display and read function.

Additional Questions:

1. Write a C program to write the students' records (Name, Roll No., Grade, Branch) into a text file. Read the text file and store the student records branch-wise in separate files.

LAB NO: 3 **Date:**

STACKS

Objectives:

In this lab students should be able to:

- Understand the concept of stacks.
- Implement the concept of stacks.
- Write and execute the application programs for stacks

Introduction:

The stack and the queue are data types that support insertion and deletion operations with well-defined semantics. Stack deletion deletes the element in the stack that was inserted the last, while a queue deletion deletes the element in the queue that was inserted the earliest. For this reason, the stack is often referred to as a LIFO (Last in First Out) datatype.

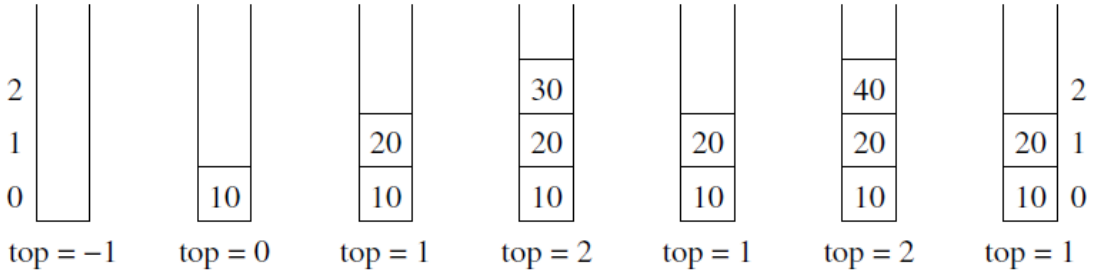


Figure: Stack Operations

Stack Implementation

Stacks and queues can be implemented using either arrays or linked lists. Although the burden of a correct stack or queue implementation appears to rest on deletion rather than insertion, it is convenient in actual implementations of these data types to place restrictions on the insertion operation as well. For example, in an array implementation of a stack, elements are inserted in a left-to-right order. A stack deletion simply deletes the right most element. A simple array implementation of a stack class is shown below:

```
struct Stack {
   int items[MAX_SIZE];
   int top;
};
```

Solved Exercise

[Implement the stack using arrays.**]**

```
#include <stdio.h>

#define MAX_SIZE 100

// Structure to represent the stack
struct Stack {
    int items[MAX_SIZE];
    int top;
};

// Function to initialize the stack
void initialize(struct Stack *stack) {
    stack->top = -1;
}

// Function to check if the stack is empty
bool isEmpty(struct Stack *stack) {
    return stack->top == -1;
}

// Function to check if the stack is full
bool isFull(struct Stack *stack) {
    return stack->top == MAX_SIZE - 1;
}

// Function to push an item onto the stack
void push(struct Stack *stack, int item) {
    if (isFull(stack)) {
        printf("Stack overflow, cannot push %d\n", item);
        return;
    }
```

```
    stack->top++;
    stack->items[stack->top] = item;
}

// Function to pop an item from the stack
int pop(struct Stack *stack) {
    if (isEmpty(stack)) {
        printf("Stack underflow, cannot pop\n");
        return -1; // Return an error value
    }

    int poppedItem = stack->items[stack->top];
    stack->top--;

    return poppedItem;
}

// Function to peek at the top item of the stack without removing it
int peek(struct Stack *stack) {
    if (isEmpty(stack)) {
        printf("Stack is empty, cannot peek\n");
        return -1; // Return an error value
    }

    return stack->items[stack->top];
}

int main() {
    struct Stack stack;
    initialize(&stack);

    int choice, item;
    while (true) {
        printf("\n--- Stack Menu ---\n");
```

```
        printf("1. Push\n");
        printf("2. Pop\n");
        printf("3. Peek\n");
        printf("4. Exit\n");
        printf("Enter your choice: ");
        scanf("%d", &choice);

        switch (choice) {
            case 1:
                printf("Enter the item to push: ");
                scanf("%d", &item);
                push(&stack, item);
                break;
            case 2:
                item = pop(&stack);
                if (item != -1)
                    printf("Popped item: %d\n", item);
                break;
            case 3:
                item = peek(&stack);
                if (item != -1)
                    printf("Top item: %d\n", item);
                break;
            case 4:
                printf("Exiting...\n");
                return 0;
            default:
                printf("Invalid choice, please try again.\n");
        }
    }

    return 0;
}
```

Lab Exercise:

1. Write a C program to check whether a given string is a palindrome or not using stacks.
2. Write a C program to convert a given decimal number to a number in any base using stack.

Additional Exercise

1. Write a C program to implement Multiple stacks using arrays.

2. Write a C program to check for matching parenthesis in a given expression.

LAB NO: 4 **Date:**

QUEUES AND SPARSE MATRICES

Objectives:

In this lab students should be able to:

- Understand the concept of queues and sparse matrices.
- Implement the concept of queues and sparse matrices.
- Write and execute the application programs for sparse matrices

Introduction:

Queues are data types that support insertion and deletion operations with well-defined semantics. The queue is an FIFO (First In First out) data type. A dequeue (double ended queue) combines the stack and the queue by supporting both types of deletions. An array implementation of a queue is a bit trickier than that of a stack. Insertions can be made in a left-to-right fashion as with a stack. However, deletions must now be made from the left.

Consider a simple example of an array of size 5 into which the integers 10, 20, 30, 40 and 50 are inserted What if we are now required to insert the integer 60. On one hand, it appears that we are out of room as there is no more place to the right of 50. On the other hand, there are three locations available to the left of 40.

Figure: Queue Example

Solved Exercise:

[Implement Queue using arrays]

```
struct Queue {
   int front, rear;
   int q[Q_SIZE];
};

void insertq(struct Queue *queue, int item);
int delq(struct Queue *queue);
```

```
void display(struct Queue *queue);

int main() {
    struct Queue queue;
    queue.front = 0;
    queue.rear = -1;

    int choice, item;
    while (1) {
        printf("\n1. Insert an element\n");
        printf("2. Delete an element\n");
        printf("3. Display the queue\n");
        printf("4. Exit\n");
        printf("Enter your choice: ");
        scanf("%d", &choice);

        switch (choice) {
            case 1:
                printf("Enter the element to insert: ");
                scanf("%d", &item);
                insertq(&queue, item);
                break;
            case 2:
                item = delq(&queue);
                if (item != -1)
                    printf("Deleted item: %d\n", item);
                else
                    printf("Queue is empty.\n");
                break;
            case 3:
                display(&queue);
                break;
            case 4:
                printf("Exiting the program.\n");
                return 0;
```

```
            default:
                printf("Invalid choice! Please try again.\n");
        }
    }

    return 0;
}

void insertq(struct Queue *queue, int item) {
    if (queue->rear == Q_SIZE - 1) {
        printf("Queue overflow\n");
        return;
    }

    queue->rear++;
    queue->q[queue->rear] = item;
}

int delq(struct Queue *queue) {
    if (queue->front > queue->rear)
        return -1;

    int deletedItem = queue->q[queue->front];
    queue->front++;
    return deletedItem;
}

void display(struct Queue *queue) {
    if (queue->front > queue->rear) {
        printf("Empty queue\n");
        return;
    }

    printf("Contents:");
    for (int i = queue->front; i <= queue->rear; i++)
```

```
        printf(" %d", queue->q[i]);
    printf("\n");
}
```

Lab Exercise:

1. Write a program in C to implement the circular queue using arrays.
2. Write a program in C to find the fast transpose of a sparse matrix represented using array of objects.

Additional Questions:

1. Write a program in C to find the transpose of a sparse matrix represented using array of objects.

LAB NO.5 **Date:**

APPLICATIONS OF STACKS - I

Objectives:

In this lab students should be able to:

- Write and execute the application programs for stacks

Introduction to the arithmetic expression conversion techniques:

Infix to postfix conversion: There is an algorithm to convert an infix expression into a postfix expression. It uses a stack; but in this case, the stack is used to hold operators rather than numbers. The purpose of the stack is to reverse the order of the operators in the expression. It also serves as a storage structure, since no operator can be printed until both of its operands have appeared.

Example: A * B + C becomes A B * C +

The order in which the operators appear is not reversed. When the '+' is read, it has lower precedence than the '*', so the '*' must be printed first.

We will show this in a table with three columns. The first will show the symbol currently being read. The second will show what is on the stack and the third will show the current contents of the postfix string. The stack will be written from left to right with the 'bottom' of the stack to the left.

	current symbol	operator stack content	postfix string
1	A		A
2	*	*	A
3	B	*	A B
4	+	+	A B * {pop and print the '*' before pushing the '+'}
5	C	+	A B * C
6	‘\0’		A B * C +

Lab Exercise:

1. Write a program to input an infix expression and convert into its equivalent post fix form and display. Operands can be single character.
2. Write a program to evaluate a postfix expression. The input to the program is a postfix expression.
3. Write a program that converts a post fix expression to a fully parenthesized infix expression.

Additional Exercise:

1. Write a program to implement queue data structure using stack.

LAB NO. 6 **Date:**

APPLICATIONS OF STACKS - II

Objectives:

In this lab students should be able to:

- Write and execute the application programs for stacks

Lab Exercise:

1. Write a program to input an infix expression and convert into its equivalent prefix form and display. Operands can be single character.
2. Write a program to evaluate prefix expression. The input to the program is a prefix expression.
3. Write a program that converts a prefix expression to a fully parenthesized infix expression.

Additional exercise:

1. Write a program to convert prefix expression to postfix.

LAB NO. 7 **Date:**

LINKED LIST

Objectives:

In this lab, student will be able to:

- Understand and implement the concept of Linked list.
- Implement the applications of Linked List.

Introduction:

The linked list is an alternative to the array when a collection of objects is to be stored. The linked list is implemented using pointers. Thus, an element (or node) of a linked list contains the actual data to be stored *and* a pointer to the next node. Recall that a pointer is simply the address in memory of the next node. Thus a key difference from arrays is that a linked list does not have to be stored contiguously in memory.

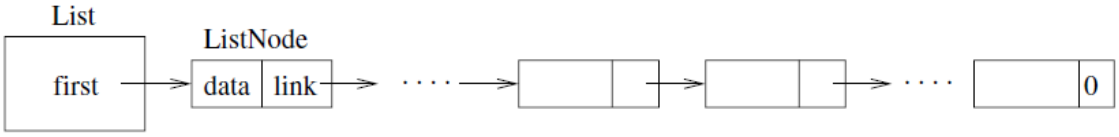


Figure: Structure of a Linked List

The code fragment below defines a linked list data structure, which is illustrated in Figure

```
struct ListNode {
        int data;
        ListNode *link;
        }
```

A chain is a linked list where each node contains a pointer to the next node in the list. The last node in the list contains a null (or zero) pointer.

Solved exercise

[Understand the concept of linked list and implement it]

Write a menu driven program to perform the following operations on linked list.

i) Create a list. ii) Display the list**.** iii) Delete the list

```
typedef struct Node {
    int data;
    struct Node* next;
} Node;

// Function prototypes
Node* createNode(int data);
Node* insert(Node* head, int data);
Node* delete(Node* head, int data);
void display(Node* head);

int main() {
    Node* head = NULL;
    int choice, data;

    while (1) {
        printf("\n1. Insert an element\n");
        printf("2. Delete an element\n");
        printf("3. Display the linked list\n");
        printf("4. Exit\n");
        printf("Enter your choice: ");
        scanf("%d", &choice);

        switch (choice) {
            case 1:
                printf("Enter the element to insert: ");
                scanf("%d", &data);
                head = insert(head, data);
                break;
            case 2:
                printf("Enter the element to delete: ");
                scanf("%d", &data);
                head = delete(head, data);
                break;
            case 3:
```

```
            display(head);
            break;
        case 4:
            printf("Exiting the program.\n");
            return 0;
        default:
            printf("Invalid choice! Please try again.\n");
      }
   }
   return 0;
}

// Function to create a new node
Node* createNode(int data) {
   Node* newNode = (Node*)malloc(sizeof(Node));
   newNode->data = data;
   newNode->next = NULL;
   return newNode;
}

// Function to insert a new element at the end of the linked list
Node* insert(Node* head, int data) {
   Node* newNode = createNode(data);

   if (head == NULL) {
      head = newNode;
   } else {
      Node* current = head;
      while (current->next != NULL) {
         current = current->next;
      }
      current->next = newNode;
   }
   return head;
}
```

```
// Function to delete an element from the linked list
Node* delete(Node* head, int data) {
    if (head == NULL) {
        printf("Linked list is empty.\n");
        return NULL;
    }

    Node* current = head;
    Node* prev = NULL;

    while (current != NULL && current->data != data) {
        prev = current;
        current = current->next;
    }

    if (current == NULL) {
        printf("Element not found in the linked list.\n");
        return head;
    }

    if (prev == NULL) {
        head = current->next;
    } else {
        prev->next = current->next;
    }

    free(current);
    printf("Element deleted successfully.\n");
    return head;
}

// Function to display the elements of the linked list
void display(Node* head) {
    if (head == NULL) {
        printf("Linked list is empty.\n");
```

```
        return;
    }

    Node* current = head;
    printf("Linked list elements: ");
    while (current != NULL) {
        printf("%d ", current->data);
        current = current->next;
    }
    printf("\n");
}
```

Lab exercises

1. Write a menu driven program to perform the following operations on linked list.
   i) Insert an element before another element in the existing list
   ii) Insert an element after another element in the existing list
   iii) Delete a given element from the list
   iv) Traverse the list
   v) Reverse the list
   vi) Sort the list
   vii) Delete every alternate node in the list
   viii) Insert an element in a sorted list such that the order is maintained.

Additional Questions:

1. Write recursive functions for i) Creating a linked list ii) Traversing a linked list.
2. Let X = (x_1, x_2….x_n) and Y = (y_1, y_2….y_n) be 2 linked lists. Assume that, in each list, the nodes are in non-decreasing order of the data field values. Write an algorithm to merge two lists to obtain a new linked list Z in which the nodes are also in the non-decreasing order. Following the merge, X and Y do not exist as individual lists. Each node initially in X or Y is now in Z. Do not use additional nodes.
3. Let list1 = (x_1, x_2…..x_n) and list2= (y_1, $y_{2…..}y_m$). Write a function to merge list1 and list2 to obtain list3 = (x_1, y_1, x_2, y_2….x_m,y_m,x_{m+1}…x_n) for m<=n; and list3=(x_1, y_1,x_2,$y_{2…..}x_n$, y_n, $x_{n+1….}x_m$) for m>n.
4. Write a program to implement stack & queue using Singly linked lists.

LAB NO: 8 **Date:**

DOUBLY LINKED LIST

Objectives:

In this lab, student will be able to:

- Write and execute programs on doubly linked list and applications of singly linked list.

Introduction to Doubly Linked List:

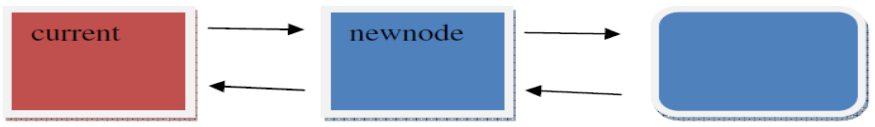
A doubly linked list is a list that contains links to next and previous nodes. Unlike singly linked lists where traversal are only one way, doubly linked lists allow traversals in both ways. A generic doubly linked list node can be designed as:

```
struct dnode
        {
          int info;
          struct dnode *prev;
          struct dnode *next;
        } ;
```

The design of the node allows flexibility of storing any data type as the linked list data.

Inserting to a Doubly Linked Lists

Suppose a new node, *new node* needs to be inserted after the node *current*,



The following code can then be written

newnode➔ next = current➔next; current➔next = newnode;

newnode➔prev = current; (newnode➔next)➔prev = newnode;

Doubly linked lists (DLL) are also widely used in many applications that deals with dynamic memory allocation and deallocation.

Deleting a Node from a Doubly Linked Lists

Suppose a new node, **current** needs to be deleted

The following code can then be written

node* N = current➔prev

N➔ next = current➔next;

(N➔next)➔prev = N;

free(current);

Solved exercise

[Write a program to create and display doubly linked list using the header node]

```
typedef struct Node {
    int data;
    struct Node* next;
    struct Node* prev;
} Node;

// Function prototypes
Node* createNode(int data);
void insert(Node* header, int data);
void display(Node* header);

int main() {
```

```
    Node* header = createNode(-1); // Header node with data -1

    int choice, data;
    while (1) {
        printf("\n1. Insert an element\n");
        printf("2. Display the doubly linked list\n");
        printf("3. Exit\n");
        printf("Enter your choice: ");
        scanf("%d", &choice);

        switch (choice) {
            case 1:
                printf("Enter the element to insert: ");
                scanf("%d", &data);
                insert(header, data);
                break;
            case 2:
                display(header);
                break;
            case 3:
                printf("Exiting the program.\n");
                return 0;
            default:
                printf("Invalid choice! Please try again.\n");
        }
    }

    return 0;
}

// Function to create a new node
Node* createNode(int data) {
    Node* newNode = (Node*)malloc(sizeof(Node));
    newNode->data = data;
    newNode->next = NULL;
```

```
    newNode->prev = NULL;
    return newNode;
}

// Function to insert a new element at the end of the doubly linked list
void insert(Node* header, int data) {
    Node* newNode = createNode(data);

    Node* current = header;
    while (current->next != NULL) {
        current = current->next;
    }

    current->next = newNode;
    newNode->prev = current;
}

// Function to display the elements of the doubly linked list
void display(Node* header) {
    if (header->next == NULL) {
        printf("Doubly linked list is empty.\n");
        return;
    }

    Node* current = header->next;
    printf("Doubly linked list elements: ");
    while (current != NULL) {
        printf("%d ", current->data);
        current = current->next;
    }
    printf("\n");
}
```

Lab exercises

1. Write a menu driven program to perform the following on a doubly linked list

i.) Insert an element at the rear end of the list
ii.) Delete an element from the rear end of the list
iii.) Insert an element at a given position of the list
iv.) Delete an element from a given position of the list
v.) Insert an element after another element
vi.) Insert an element before another element
vii.) Traverse the list
viii.) Reverse the list

2. Write a program to concatenate two doubly linked lists X1 and X2. After concatenation X1 is a pointer to first node of the resulting lists.

Additional Questions:

1. Write a program to implement union and intersection of two doubly linked lists.
2. Write a program to implement addition of two long positive integer numbers.

LAB NO: 9 **Date:**

POLYNOMIALS USING LINKED LIST AND CIRCULAR LIST

Objectives:

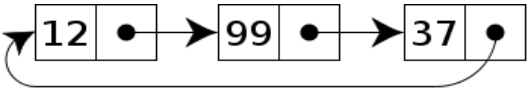
In this lab, student will be able to:

- Write and execute programs on circular list and polynomials

Introduction to polynomials and circular list

Circular List:

In the last node of a list, the link field often contains a null reference, a special value used to indicate the lack of further nodes. A less common convention is to make it point to the first node of the list; in that case the list is said to be 'circular' or 'circularly linked'; otherwise it is said to be 'open' or 'linear'.



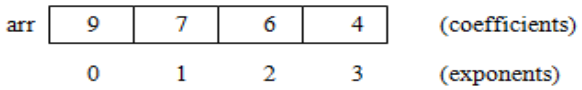
In the case of a circular doubly linked list, the only change that occurs is that the end, or "tail", of the said list is linked back to the front, or "head", of the list and vice versa.

Polynomials:

A polynomial is an expression that contains more than two terms. A term is made up of coefficient and exponent. An example of polynomial is

$P(x) = 4x^3+6x^2+7x+9$

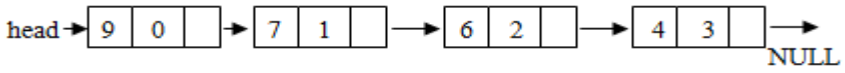
A polynomial thus may be represented using arrays or linked lists. Array representation assumes that the exponents of the given expression are arranged from 0 to the highest value (degree), which is represented by the subscript of the array beginning with 0. The coefficients of the respective exponent are placed at an appropriate index in the array. The array representation for the above polynomial expression is given below:



A polynomial may also be represented using a linked list. A structure may be defined such that it contains two parts- one is the coefficient and second is the corresponding exponent. The class definition may be given as shown below:

```
struct polynomial
{
   int coefficient;
   int exponent;
   struct polynomial *next;
};
```

Thus the above polynomial may be represented using linked list as shown below:



Lab exercises

1. Write a menu driven program to:
   ii) Insert an element into a doubly linked circular list
   iii) Delete an element from a doubly linked circular list.
2. Write a program to add 2 polynomials represented as linked lists.

Additional Exercise:

1. Write a program to multiply two polynomials using circular doubly linked list with header node.
2. Write a program to add 2 polynomials using circular doubly linked list with head node.
3. Develop a C application to simulate a washing machine renting system using a circular doubly linked list. User books the washing machine for a certain amount of time and soon after the time duration, the washing machine will be handed over to the next person in the queue for use.

LAB NO: 10 **Date:**

TREES

Objectives:

In this lab, student will be able to:

- Understand and implement the concept of binary trees.
- Implement the traversal techniques and few applications based on traversal techniques of binary trees

Introduction:

Any tree can be represented as a binary tree. In fact binary trees are an important type of tree structure that occurs very often. The chief characteristics of a binary tree are the stipulation that the degree of any given node must not exceed two. A binary tree may have zero nodes. To define a binary tree formally- "A binary tree is a finite set of nodes that is either empty or consists of a root and two disjoint binary trees called left subtree and right subtree.

Inorder Traversal: Informally, inorder traversal calls for moving down the tree toward the left until you can go no further. Then you "visit" the node, move one node to the right and continue. If you cannot move to the right, go back one more node. The pseudocode for inorder traversal is as given below:

```
void inorder(node *root)
{
  if(root==NULL) return;
  inroder(root→llink);
  cout<< root→info;
  inroder(root→rlink);
}
```

Preorder Traversal:

```
void preorder(node *root)
{
 if(root==NULL)return;
 cout<< root→info;
```

```
  preorder(root→llink);
  preorder(root→rlink);
 }
```

Post Order Traversal:

```
void postorder(node *root)
{
  if(root==NULL)return;
  postorder(root→llink);
  postorder(root→rlink);
  cout<< root→info;
 }
```

Lab exercises

1. Write user defined functions to perform the following operations on binary trees.
    i.) In order traversal (Iterative)
    ii.) Post order traversal (Iterative)
    iii.) Preorder traversal(Iterative)
    iv.) Print the parent of the given element
    v.) Print the depth of the tree
    vi.) Print the ancestors of a given element
    vii.) Count the number of leaf nodes in a binary tree
2. Write a recursive function to i) Create a binary tree and ii) print a binary tree

Additional exercise:

1. Write a program to check for equality of two trees.
2. Write a program to check if one tree is the mirror image of another tree.
3. Write a program to copy one tree to another.

LAB NO: 11 **Date:**

BINARY SEARCH TREES

Objectives:

In this lab, student will be able to:

1. Understand concept of Binary Search Tree
2. Write and execute the programs for BST.

Introduction:

A binary search tree is a rooted binary tree, whose internal nodes store a key (and optionally, an associated value) and each have two distinguished sub-trees, commonly denoted *left* and *right*. The tree additionally satisfies the binary search tree property, which states that the key in each node must be greater than all keys stored in the left sub-tree, and smaller than all keys in right sub-tree.

The major advantage of binary search trees over other data structures is that the related sorting algorithms and search algorithms such as in-order traversal can be very efficient; they are also easy to code.

Insertion:

Insertion begins as a search would begin; if the key is not equal to that of the root, we search the left or right subtrees as before. Eventually, we will reach an external node and add the new key-value pair (here encoded as a record 'newNode') as its right or left child, depending on the node's key. In other words, we examine the root and recursively insert the new node to the left subtree if its key is less than that of the root, or the right subtree if its key is greater than or equal to the root.

```
void insert(Node* root, int data)
 {if (!root)
        root = new Node(data);
elseif (data < root→data)
        insert(root→left, data);
elseif (data > root→data)
        insert(root→right, data);
}
```

Deletion:

There are three possible cases to consider:

- Deleting a node with no children: simply remove the node from the tree.
- Deleting a node with one child: remove the node and replace it with its child.
- Deleting a node with two children: call the node to be deleted *N*. Do not delete *N*. Instead, choose either its in-order successor node or its in-order predecessor node, *R*. Copy the value of *R* to *N*, then recursively call delete on *R* until reaching one of the first two cases. If you choose in-order successor of a node, as right sub tree is not NIL (Our present case is node has 2 children), then its in-order successor is node with least value in its right sub tree, which will have at a maximum of one sub tree, so deleting it would fall in one of first two cases.

Lab exercises

1. Write a program to insert an element into a binary search tree.
2. Write a program to delete an element from a binary search tree.
3. Write a program to search for a given element in a binary search tree.
4. Write a program to traverse a binary search tree and print it.

Additional exercise:

1. Write a program to implement level order traversal on binary search tree
2. Write a program to create a tree for a postfix expression and evaluate it.

LAB NO: 12 **Date:**

SORTING TECHNIQUES

Objective:

In this lab students should be able to:

- Understand the concept of Sorting.
- Implement different types of sorting techniques

Introduction:

A **sorting algorithm** is an algorithm that puts elements of a list in a certain order. The most-used orders are numerical order and lexicographical order. Efficient sorting is important for optimizing the use of other algorithms (such as search and merge algorithms) which require input data to be in sorted lists; it is also often useful for canonicalizing data and for producing human-readable output.

Quick Sort:

Quicksort is a divide and conquer algorithm which relies on a *partition* operation: to partition an array. An element called a *pivot* is selected. All elements smaller than the pivot is moved before it; all greater elements are moved after it. This can be done efficiently in linear time and in-place. The lesser and greater sublists are then recursively sorted. This yields average time complexity of O(n log n), with low overhead, and thus this is a popular algorithm. Efficient implementations of quicksort (with in-place partitioning) are typically unstable sorts and somewhat complex, but are among the fastest sorting algorithms in practice.
The steps are:

1. Pick an element, called a **pivot**, from the array.
2. Reorder the array so that all elements with values less than the pivot come before the pivot, while all elements with values greater than the pivot come after it (equal values can go either way). After this partitioning, the pivot is in its final position. This is called the **partition** operation.
3. Recursively apply the above steps to the sub-array of elements with smaller values and separately to the sub-array of elements with greater values.

The base case of the recursion is arrays of size zero or one, which can never be sorted

Lab Exercise:

1. Write a program to sort a given list of elements using
    i. Quick sort
    ii. Heap sort
    iii. Radix sort
    iv. Merge sort

REFERENCES

1. Behrouz A. Forouzan, Richard F. Gilberg, A Structured Programming Approach Using C,3rd Edition, Cengage Learning India Pvt. Ltd, India, 2007.
2. Ellis Horowitz, Sartaj Sahani, Susan Anderson and Freed, Fundamentals of Data Structures in C, 2nd Edition, Silicon Press, 2007.
3. Richard F. Gilberg, Behrouz A. Forouzan, Data structures, A Pseudocode Approach with C, 2nd Edition, Cengage Learning India Pvt. Ltd, India , 2009.
4. Tenenbaum Aaron M., Langsam Yedidyah, Augenstein Moshe J., Data structures using C, Pearson Prentice Hall of India Ltd., 2007.
5. Debasis Samanta, Classic Data Structures, 2nd Edition, PHI Learning Pvt. Ltd., India, 2010. .

C QUICK REFERENCE

PREPROCESSOR

```
                        // Comment to end of line
                        /* Multi-line comment */
#include <stdio.h>      // Insert standard header file
#include "myfile.h"         // Insert file in current directory
#define X some text             // Replace X with some text
#define F(a,b) a+b      // Replace F(1,2) with 1+2
#define X \
        some text       // Line continuation
#undef X                // Remove definition
#if defined(X)          // Condional compilation (#ifdef X)
#else                   // Optional (#ifndef X or #if !defined(X))
#endif                  // Required after #if, #ifdef
```

LITERALS

```
255, 0377, 0xff                 // Integers (decimal, octal, hex)
2147463647L, 0x7fffffffl        // Long (32-bit) integers
123.0, 1.23e2           // double (real) numbers
‘a’, ‘\141’, ‘\x61’             // Character (literal, octal, hex)
‘\n’, ‘\\’, ‘\’’, ‘\””,         // Newline, backslash, single quote, double quote
“string\n”              // Array of characters ending with newline and \0
“hello” “world”                 // Concatenated strings
true, false             // bool constants 1 and 0
```

DECLARATIONS

```
int x;                  // Declare x to be an integer (value undefined)
int x=255;              // Declare and initialize x to 255
short s; long 1;        // Usually 16 or 32 bit integer (int may be either)
char c= ‘a’;            // Usually 8 bit character
unsigned char u=255; signed char m=-1; // char might be either
unsigned long x=0xffffffffL; // short, int, long are signed
float f; double d;              // Single or double precision real (never unsigned)
bool b=true;            // true or false, may also use int (1 or 0)
```

```
int a, b, c;                // Multiple declarations
int a[10];                  // Array of 10 ints (a[0] through a[9])
int a[]={0,1,2};                    // Initialized array (or a[3]={0,1,2}; )
int a[2][3]={{1,2,3},{4,5,6}; // Array of array of ints
char s[]= “hello”;                  // String (6 elements including ‘\0’)
int* p;                     // p is a pointer to (address of) int
char* s= “hello”;                   // s points to unnamed array containing "hello"
void* p=NULL;                       // Address of untyped memory (NULL is 0)
int& r=x;                   // r is a reference to (alias of) int x
enum weekend {SAT, SUN};// weekend is a type with values SAT and SUN
enum weekend day;           // day is a variable of type weekend
enum weekend {SAT=0,SUN=1}; // Explicit representation as int
enum {SAT,SUN} day;         // Anonymous enum
typedef String char*;  // String s; means char* s;
constint c=3;               // Constants must be initialized, cannot assign
constint* p=a;              // Contents of p (elements of a) are constant
int* const p=a;             // p (but not contents) are constant
constint* const p=a;   // Both p and its contents are constant
                    =x;             // cr cannot be assigned to change x
```

STORAGE CLASSES

```
int x;                      // Auto (memory exists only while in scope)
staticint x;                // Global lifetime even if local scope
externint x;                // Information only, declared elsewhere
```

STATEMENTS

```
x=y;                        // Every expression is a statement
int x;                      // Declarations are statements
;                           // Empty statement
{                           // A block is a single statement
int x;                      // Scope of x is from declaration to end of
block
a;                          // In C, declarations must precede statements
}
if (x) a;                   // If x is true (not 0), evaluate a
```

```
else if (y) b;          // If not x and y (optional, may be repeated)
else c;                 // If not x and not y (optional)
while (x) a;            // Repeat 0 or more times while x is true
for (x; y; z) a;        // Equivalent to:  x; while(y) {a; z;}
do a; while (x);                // Equivalent to:  a; while(x) a;
switch (x) {            // x must be int
        case X1: a;     // If x == X1 (must be a const), jump here
        case X2: b;     // Else if x == X2, jump here
        default: c;     // Else jump here (optional)
}
break;                  // Jump out of while, do, for loop, or switch
continue;               // Jump to bottom of while, do, or for loop
return x;                       // Return x from function to caller
try { a; }
catch (T t) { b; }              // If a throws T, then jump here
catch (...)  { c; }             // If a throws something else, jump here
```

FUNCTIONS

```
int f(int x, int);              // f is a function taking 2 ints and returning int
void f();                       // f is a procedure taking no arguments
void f(int a=0);                // f() is equivalent to f(0)
f();                    // Default return type is int
inline f();             // Optimize for speed
f( ) { statements; }    // Function definition (must be global)
```

Function parameters and return values may be of any type. A function must either be declared or defined before it is used. It may be declared first and defined later. Every program consists of a set of global variable declarations and a set of function definitions (possibly in separate files), one of which must be:

```
int main() { statements... }      or
int main(intargc, char* argv[]) { statements... }
```

argv is an array of argc strings from the command line. By convention, main returns status 0 if successful, 1 or higher for errors.

EXPRESSIONS

Operators are grouped by precedence, highest first. Unary operators and assignment evaluate right to left. All others are left to right. Precedence does not affect order of evaluation which is undefined. There are no runtime checks for arrays out of bounds, invalid pointers etc.

```
T::X            // Name X defined in class T
N::X            // Name X defined in namespace N
::X             // Global name X
t.x             // Member x of struct or class t
p → x           // Member x of struct or class pointed to by p
a[i]            // i'th element of array a
f(x, y)         // Call to function f with arguments x and y
T(x, y)             // Object of class T initialized with x and y
x++             // Add 1 to x, evaluates to original x (postfix)
x--             // Subtract 1 from x, evaluates to original x
sizeof x            // Number of bytes used to represent object x
sizeof(T)       // Number of bytes to represent type T
++x             // Add 1 to x, evaluates to new value (prefix)
--x             // Subtract 1 from x, evaluates to new value
~x              // Bitwise complement of x
!x              // true if x is 0, else false (1 or 0 in C)
-x              // Unary minus
+x              // Unary plus (default)
&x              // Address of x
*p              // Contents of address p (*&x equals x)
x * y           // Multiply
x / y           // Divide (integers round toward 0)
x % y           // Modulo (result has sign of x)
x + y           // Add, or &x[y]
x – y           // Subtract, or number of elements from *x to *y
x << y          // x shifted y bits to left (x * pow(2, y))
x >> y          // x shifted y bits to right (x / pow(2, y))
x < y           // Less than
x <= y          // Less than or equal to
x > y           // Greater than
```

```
x >= y          // Greater than or equal to
x == y          // Equals
x != y          // Not equals
x& y            // Bitwise and (3 & 6 is 2)
x ^ y           // Bitwise exclusive or (3 ^ 6 is 5)
x | y           // Bitwise or (3 | 6 is 7)
x&& y           // x and then y (evaluates y only if x (not 0))
x || r              // x or else y (evaluates y only if x is false(0))
x = y                   // Assign y to x, returns new value of x
x += y                  // x = x + y, also -= *= /= <<= >>= &= |= ^=
x ?y : z                        // y if x is true (nonzero), else z
throw x                         // Throw exception, aborts if not caught
                        // evaluates x and y, returns y (seldom used)
```

IOSTREAM.H, IOSTREAM

```
cin>> x >> y;           // Read words x and y (any type) from stdin
cout<< "x=" << 3 <<endl; // Write line to stdout
cerr « x « y « flush;   // Write to stderr and flush
c = cin.get();          // c = getchar();
cin.get(c);             // Read char
cin.getline(s, n, '\n'); // Read line into char s[n] to '\n', (default)
if (cin)                // Good state (not EOY)?
                        // To read/write any type T:
```

STRING (Variable sized character array)

```
string s1, s2= "hello";     //Create strings
sl.size(), s2.size();       // Number of characters: 0, 5
sl += s2 +  '  ' + "world"; // Concatenation
sl == "hello world";        // Comparison, also <, >, !=, etc.
s1[0];                      // 'h'
sl.substr(m, n);                    // Substring of size n starting at sl[m]
sl.c_str();                 // Convert to const char*
getline(cin, s);            // Read line ending in '\n'
```

```
asin(x); acos(x); atan(x);          // Inverses
atan2(y, x);                  // atan(y/x)
sinh(x); cosh(x); tanh(x);          // Hyperbolic
exp(x); log(x); log10(x);           // e to the x, log base e, log base 10
pow(x, y); sqrt(x);           // x to the y, square root
ceil(x); floor(x);                  // Round up or down (as a double)
fabs(x); fmod(x, y);          // Absolute value, x mod y
```