The University of Faisalabad

Submitted to:

Ma’am Irsha Qureshi

Submitted by:

Ayesha Imran

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03

FINAL ASSINGMENT

Doubly Linked List

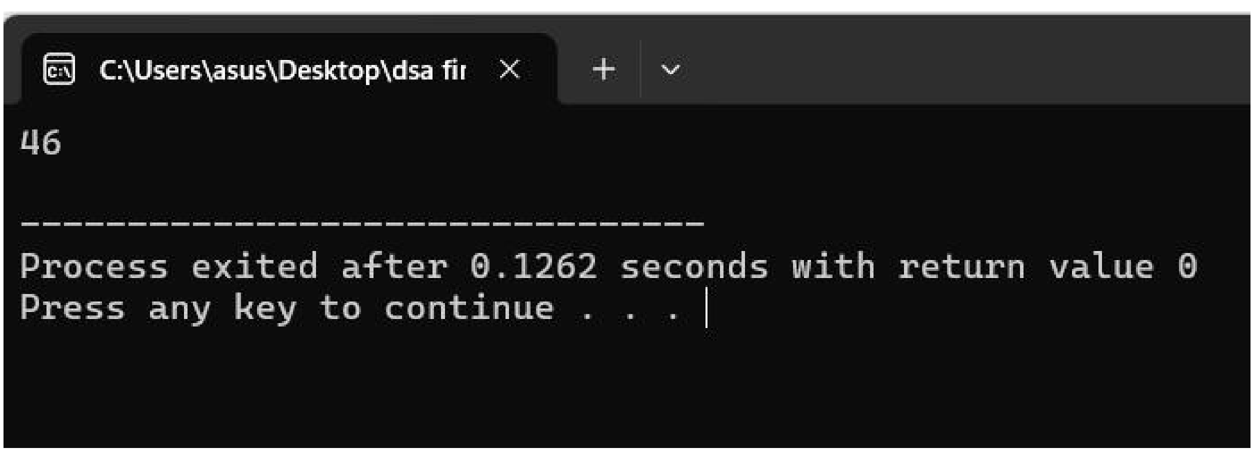
1. **Write a program to delete the first node in a doubly linked list.**

Code:

```
#include <iostream>
using namespace std;

class Node {
public:
    int val;
    Node* next;
    Node* prev;

    Node(int data) {
        val = data;
        next = NULL;
        prev = NULL;
    }
};

class DOUBLELINKLIST {
public:
    Node* head;
    Node* tail;

    DOUBLELINKLIST() {
        head = NULL;
```

```
        tail = NULL;
    }

    void insert(int val) {
    Node* new_node = new Node(val);
    if (head == NULL) { // If the list is empty
        head = new_node;
        tail = new_node;
    } else {
        tail->next = new_node; // Link the current tail to the new node
        new_node->prev = tail; // Link the new node back to the current tail
        tail = new_node;       // Update the tail to the new node
    }
}



    void deleteAThead() {
        if (head == NULL) { // If the list is empty
            return;
        }
        Node* temp = head;
        head = head->next;
        if (head == NULL) { // If the list becomes empty after deletion
            tail = NULL;
        } else {
            head->prev = NULL;
        }
        delete temp;
    }
```

```
    void display() {
        Node* temp = head;
        while (temp != NULL) {
            cout << temp->val;
            if (temp->next != NULL) { // Only add <-> between nodes
                cout << " <-> ";
            }
            temp = temp->next;
        }
        cout << endl;
    }
};

int main() {
    DOUBLELINKLIST dll;
    dll.insert(3);
    dll.insert(2);
    dll.deleteAThead();
    dll.display();
    return 0;
}
```



2. How can you delete the last node in a doubly linked list? Write the code.

Code:

```
#include <iostream>
using namespace std;

class Node {
public:
    int val;
    Node* next;
    Node* prev;

    Node(int data) {
        val = data;
        next = NULL;
        prev = NULL;
    }
};

class DOUBLELINKLIST {
public:
    Node* head;
    Node* tail;

    DOUBLELINKLIST() {
        head = NULL;
        tail = NULL;
    }

    void insert(int val) {
    Node* new_node = new Node(val);
    if (head == NULL) { // If the list is empty
```

```
        head = new_node;
        tail = new_node;
    } else {
        tail->next = new_node; // Link the current tail to the new node
        new_node->prev = tail; // Link the new node back to the current tail
        tail = new_node;       // Update the tail to the new node
    }
}


    void del(){
            if (head==NULL){
                        return;
                        }
                        Node* temp = tail;
                        tail = tail->prev;
                        if(head==NULL){
                                    tail=NULL;
                        }
                        else{
                                    tail->next = NULL;
                        }
                        delete temp;
            }

    void display() {
        Node* temp = head;
        while (temp != NULL) {
            cout << temp->val;
            if (temp->next != NULL) { // Only add <-> between nodes
```

```
            cout << " <-> ";
        }
        temp = temp->next;
    }
    cout << endl;
  }
};

int main() {
  DOUBLELINKLIST dll;
  dll.insert(3);
  dll.insert(2);
  dll.del();
  dll.display();
  return 0;
}
```

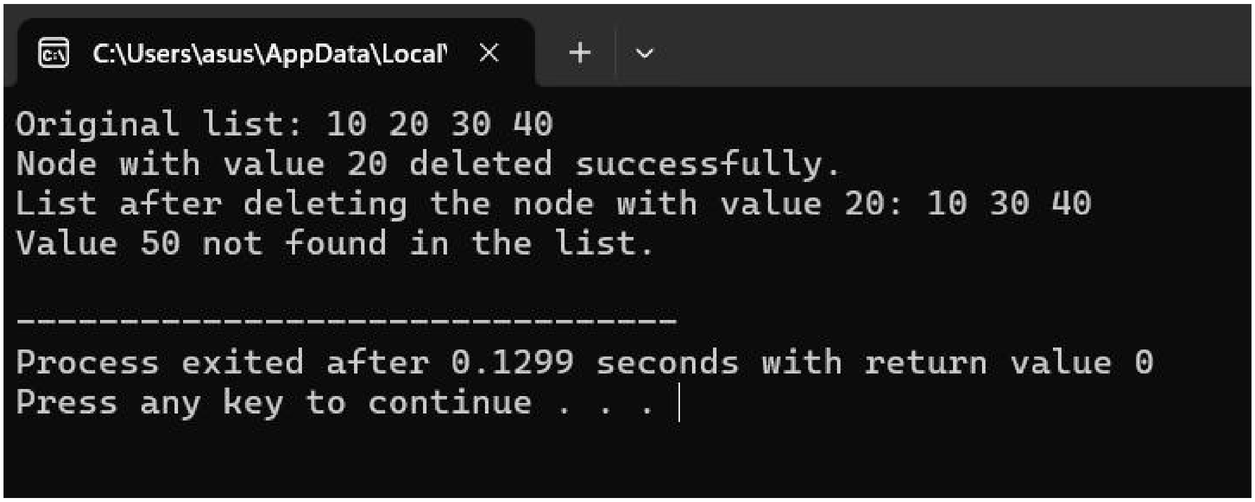
3. **Write code to delete a node by its value in a doubly linked list.**
   Code:

```
#include <iostream>
using namespace std;

// Define a Node of the doubly linked list
struct Node {
  int data;
  Node* prev;
  Node* next;

  Node(int val) : data(val), prev(nullptr), next(nullptr) {}
};

// Function to delete a node by its value in a doubly linked list
void deleteNodeByValue(Node*& head, int value) {
  if (head == nullptr) { // If the list is empty
```

```
        cout << "The list is empty." << endl;
        return;
    }

    Node* temp = head;

    // Search for the node with the specified value
    while (temp != nullptr && temp->data != value) {
        temp = temp->next;
    }

    if (temp == nullptr) { // Value not found
        cout << "Value " << value << " not found in the list." << endl;
        return;
    }

    // Node with the value found
    if (temp == head) { // If it's the head node
        head = head->next;
        if (head != nullptr) {
            head->prev = nullptr;
        }
    } else if (temp->next == nullptr) { // If it's the last node
        temp->prev->next = nullptr;
    } else { // If it's a middle node
        temp->prev->next = temp->next;
        temp->next->prev = temp->prev;
    }

    delete temp; // Free the memory of the node
    cout << "Node with value " << value << " deleted successfully." << endl;
}

// Function to display the doubly linked list
void displayList(Node* head) {
    Node* temp = head;
    while (temp != nullptr) {
        cout << temp->data << " ";
        temp = temp->next;
    }
    cout << endl;
```

```
}

// Function to insert a node at the end of the doubly linked list
void appendNode(Node*& head, int data) {
    Node* newNode = new Node(data);

    if (head == nullptr) { // If the list is empty
        head = newNode;
        return;
    }

    Node* temp = head;
    while (temp->next != nullptr) {
        temp = temp->next;
    }

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

int main() {
    Node* head = nullptr;

    // Add nodes to the doubly linked list
    appendNode(head, 10);
    appendNode(head, 20);
    appendNode(head, 30);
    appendNode(head, 40);

    cout << "Original list: ";
    displayList(head);

    // Delete a node by value
    deleteNodeByValue(head, 20);

    cout << "List after deleting the node with value 20: ";
    displayList(head);

    // Try deleting a non-existent value
    deleteNodeByValue(head, 50);
```

```
    return 0;
}
```



4. **How would you delete a node at a specific position in a doubly linked list? Show it in code.**

Code:

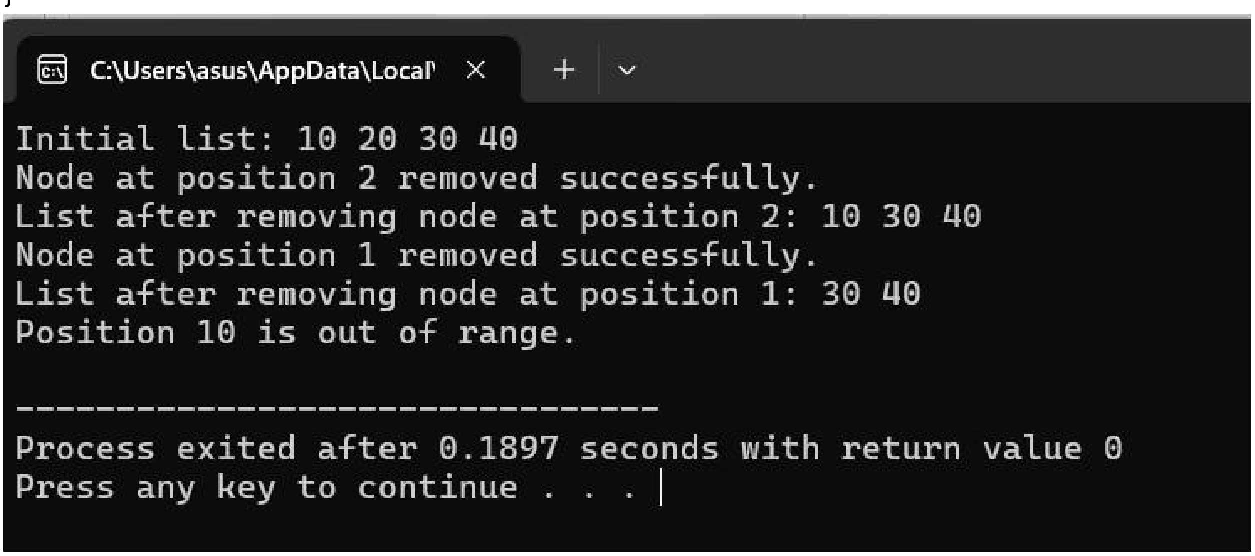
```
#include <iostream>
using namespace std;

// Structure for a Node in a doubly linked list
struct Node {
    int value;
    Node* previous;
    Node* next;

    // Constructor to initialize a node
    Node(int val) : value(val), previous(nullptr), next(nullptr) {}
};

// Function to remove a node from a specified position in the doubly linked list
void removeNodeAtPosition(Node*& head, int position) {
```

```
if (!head) { // Check if the list is empty
   cout << "The list is currently empty." << endl;
   return;
}

if (position <= 0) { // Validate the position
   cout << "Invalid position. Please provide a position greater than 0." << endl;
   return;
}

Node* current = head;
int index = 1;

// Traverse the list to locate the target position
while (current != nullptr && index < position) {
   current = current->next;
   index++;
}

if (!current) { // Position exceeds the number of nodes in the list
   cout << "Position " << position << " is out of range." << endl;
   return;
}

// Handle the removal of the node
if (current == head) { // Case: Remove the first node
   head = head->next;
```

```
        if (head) {
            head->previous = nullptr;
        }
    } else if (!current->next) { // Case: Remove the last node
        current->previous->next = nullptr;
    } else { // Case: Remove a node in the middle
        current->previous->next = current->next;
        current->next->previous = current->previous;
    }

    delete current; // Deallocate the memory
    cout << "Node at position " << position << " removed successfully." << endl;
}

// Function to display the elements of the doubly linked list
void printList(Node* head) {
    Node* temp = head;
    while (temp) { // Traverse the list and print values
        cout << temp->value << " ";
        temp = temp->next;
    }
    cout << endl;
}

// Function to add a new node to the end of the doubly linked list
void addNodeToEnd(Node*& head, int value) {
    Node* newNode = new Node(value);
```

```
    if (!head) { // Check if the list is empty
        head = newNode;
        return;
    }

    Node* current = head;
    while (current->next) { // Traverse to the last node
        current = current->next;
    }

    current->next = newNode; // Link the new node to the end
    newNode->previous = current;
}

// Main function to test the doubly linked list operations
int main() {
    Node* head = nullptr;

    // Add nodes to the list
    addNodeToEnd(head, 10);
    addNodeToEnd(head, 20);
    addNodeToEnd(head, 30);
    addNodeToEnd(head, 40);

    cout << "Initial list: ";
    printList(head);
```

```
    // Remove the node at position 2
    removeNodeAtPosition(head, 2);
    cout << "List after removing node at position 2: ";
    printList(head);

    // Remove the head node
    removeNodeAtPosition(head, 1);
    cout << "List after removing node at position 1: ";
    printList(head);

    // Attempt to remove a node at an invalid position
    removeNodeAtPosition(head, 10);

    return 0;
}
```



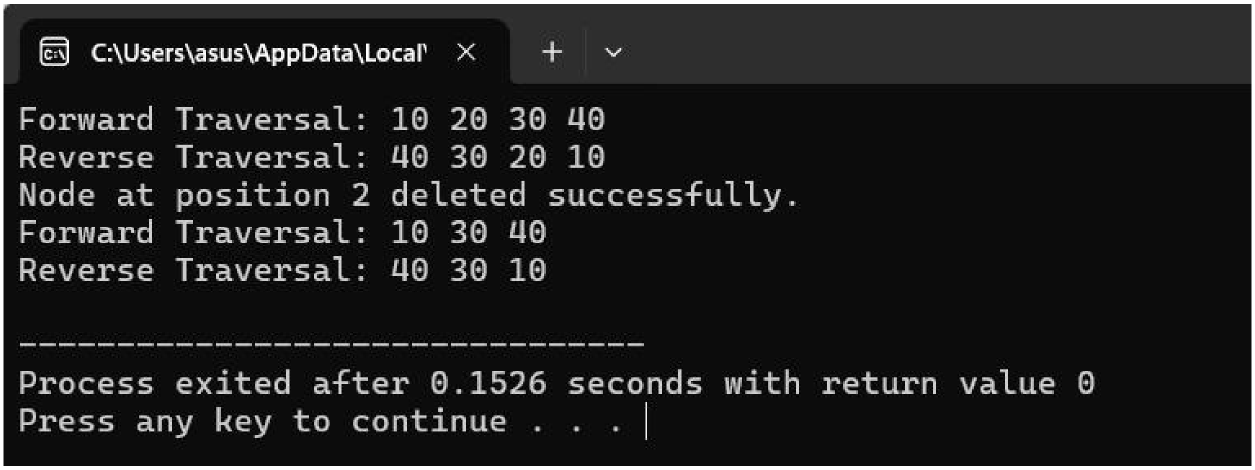
5. **After deleting a node, how will you write the forward and reverse traversal functions?**
   Code:

```
#include <iostream>
using namespace std;
struct Node {
    int data;
    Node* prev;
    Node* next;

    Node(int val) : data(val), prev(nullptr), next(nullptr) {}
};

// Function to perform forward traversal
void forwardTraversal(Node* head) {
    cout << "Forward Traversal: ";
    Node* temp = head;
    while (temp != nullptr) {
        cout << temp->data << " ";
        temp = temp->next;
    }
    cout << endl;
}

// Function to perform reverse traversal
void reverseTraversal(Node* head) {
    if (head == nullptr) { // If the list is empty
        cout << "Reverse Traversal: List is empty." << endl;
        return;
    }
 // Move to the last node
    Node* temp = head;
    while (temp->next != nullptr) {
        temp = temp->next;
    }
// Traverse backward from the last node
    cout << "Reverse Traversal: ";
    while (temp != nullptr) {
        cout << temp->data << " ";
        temp = temp->prev;
    }
    cout << endl;
}
```

```
// Function to append a node to the end
void appendNode(Node*& head, int data) {
    Node* newNode = new Node(data);

    if (head == nullptr) {
        head = newNode;
        return;
    }

    Node* temp = head;
    while (temp->next != nullptr) {
        temp = temp->next;
    }

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

// Function to delete a node at a specific position
void deleteNodeAtPosition(Node*& head, int position) {
    if (head == nullptr) { // If the list is empty
        cout << "The list is empty." << endl;
        return;
    }

    if (position <= 0) { // Invalid position
        cout << "Invalid position. Position should be greater than 0." << endl;
        return;
    }

    Node* temp = head;
    int currentIndex = 1;

    // Traverse to the node at the specified position
    while (temp != nullptr && currentIndex < position) {
        temp = temp->next;
        currentIndex++;
    }

    if (temp == nullptr) { // Position exceeds the list size
        cout << "Position " << position << " exceeds the list size." << endl;
```

```
        return;
    }

    if (temp == head) { // Deleting the head node
        head = head->next;
        if (head != nullptr) {
            head->prev = nullptr;
        }
    } else if (temp->next == nullptr) { // Deleting the last node
        temp->prev->next = nullptr;
    } else { // Deleting a middle node
        temp->prev->next = temp->next;
        temp->next->prev = temp->prev;
    }

    delete temp; // Free the memory of the node
    cout << "Node at position " << position << " deleted successfully." << endl;
}
int main() {
    Node* head = nullptr;

    // Add nodes to the doubly linked list
    appendNode(head, 10);
    appendNode(head, 20);
    appendNode(head, 30);
    appendNode(head, 40);

    // Perform forward and reverse traversal before deletion
    forwardTraversal(head);
    reverseTraversal(head);

    // Delete a node at position 2
    deleteNodeAtPosition(head, 2);

    // Perform forward and reverse after
    forwardTraversal(head);
    reverseTraversal(head);

    return 0;
```

```
}
```



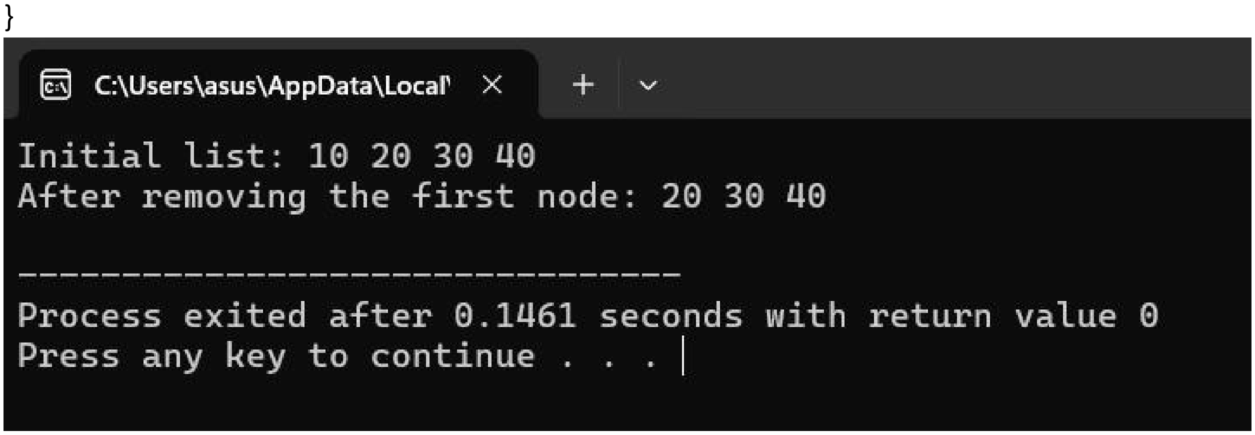
Circular Linked List

1. **Write a program to delete the first node in a circular linked list.**
   Code:

```
#include <iostream>
using namespace std;

// Structure to define a node
struct Node {
   int value;
   Node* nextNode;
};

// Function to remove the first node
void removeFirstNode(Node*& head) {
   if (!head) { // Check if the list is empty
      cout << "The list is empty. Nothing to remove." << endl;
      return;
   }

   if (head->nextNode == head) { // Single node in the list
      delete head;
      head = nullptr;
      return;
   }

   // Locate the last node in the list
```

```
    Node* lastNode = head;
    while (lastNode->nextNode != head) {
        lastNode = lastNode->nextNode;
    }

    // Update the head and adjust the last node's pointer
    Node* temp = head;
    head = head->nextNode;
    lastNode->nextNode = head;

    // Delete the old head node
    delete temp;
}

// Function to add a new node at the end of the circular linked list
void appendNode(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->value = value;
    if (!head) { // If the list is empty
        head = newNode;
        newNode->nextNode = head;
        return;
    }

    Node* current = head;
    while (current->nextNode != head) { // Traverse to the last node
        current = current->nextNode;
    }

    current->nextNode = newNode;
    newNode->nextNode = head; // Complete the circular link
}

// Function to print the contents of the circular linked list
void printList(Node* head) {
    if (!head) { // Check if the list is empty
        cout << "The list is empty." << endl;
        return;
    }

    Node* current = head;
```

```
    do {
        cout << current->value << " ";
        current = current->nextNode;
    } while (current != head);
    cout << endl;
}

// Main function to test
int main() {
    Node* head = nullptr;

    // Add nodes to the list
    appendNode(head, 10);
    appendNode(head, 20);
    appendNode(head, 30);
    appendNode(head, 40);

    cout << "Initial list: ";
    printList(head);

    // Remove the first node
    removeFirstNode(head);

    cout << "After removing the first node: ";
    printList(head);

    return 0;
}
```



2. **How can you delete the last node in a circular linked list? Write the code.**

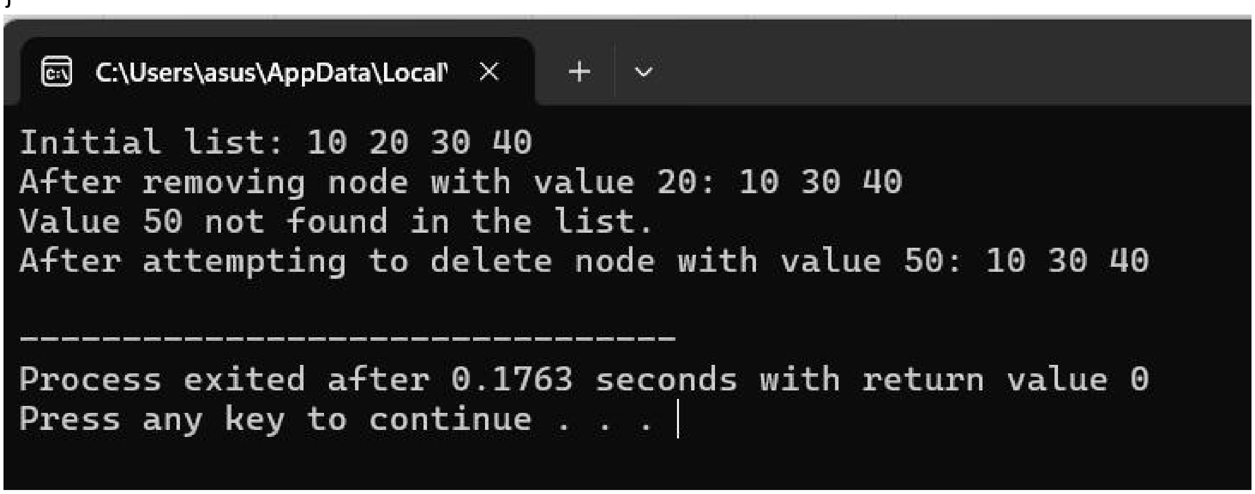
Code:

```
#include <iostream>
```

```
using namespace std;

// Node structure for circular linked list
struct Node {
   int data;
   Node* next;
};

// Function to delete a node with a specific value
void deleteNodeByValue(Node*& head, int target) {
   if (!head) { // Check if the list is empty
      cout << "The list is empty" << endl;
      return;
   }

   Node* current = head;
   Node* prev = nullptr;

   // Case 1: The list contains a single node
   if (head->data == target && head->next == head) {
      delete head;
      head = nullptr;
      return;
   }

   // Case 2: The node to delete is the head node
   if (head->data == target) {
      // Locate the last node
      while (current->next != head) {
         current = current->next;
      }
      Node* toDelete = head;
      head = head->next; // Update the head pointer
      current->next = head; // Link the last node to the new head
      delete toDelete;
      return;
   }

   // Case 3: The node to delete is in the middle or at the end
   do {
      prev = current;
```

```
        current = current->next;

        if (current->data == target) {
            prev->next = current->next;
            delete current;
            return;
        }
    } while (current != head);
    cout << "Value " << target << " not found in the list." << endl;
}
void addNodeToEnd(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->data = value;
    if (!head) {
        head = newNode;
        newNode->next = head;
        return;
    }

    Node* temp = head;
    while (temp->next != head) {
        temp = temp->next;
    }

    temp->next = newNode;
    newNode->next = head;
}

// Function to display the circular linked list
void displayList(Node* head) {
    if (!head) {
        cout << "The list is empty." << endl;
        return;
    }

    Node* temp = head;
    do {
        cout << temp->data << " ";
        temp = temp->next;
    } while (temp != head);
    cout << endl;
```

```
}
int main() {
  Node* head = nullptr;
// Add nodes to the list
  addNodeToEnd(head, 10);
  addNodeToEnd(head, 20);
  addNodeToEnd(head, 30);
  addNodeToEnd(head, 40);

  cout << "Initial list: ";
  displayList(head);

  // Remove a node
  deleteNodeByValue(head, 20);

  cout << "After removing node with value 20: ";
  displayList(head);

  //  delete a non-existent node
  deleteNodeByValue(head, 50);

  cout << "After attempting to delete node with value 50: ";
  displayList(head);

  return 0;
}
```



```
C:\Users\asus\AppData\Local\

Initial list: 10 20 30 40
After removing node with value 20: 10 30 40
Value 50 not found in the list.
After attempting to delete node with value 50: 10 30 40

--------------------------------
Process exited after 0.1763 seconds with return value 0
Press any key to continue . . .
```

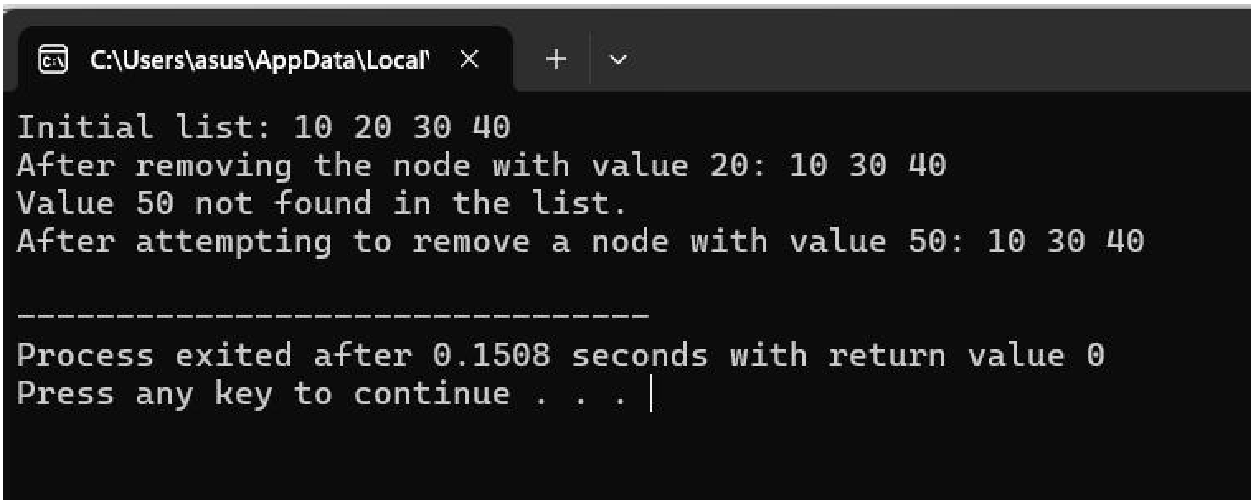
3. **Write a function to delete a node by its value in a circular linked list.**
   Code:

```
#include <iostream>
```

```
using namespace std;
struct Node {
    int value;
    Node* nextNode;
};

// Function to remove a node by its value in a circular linked list
void removeNodeByValue(Node*& head, int targetValue) {
    if (head == nullptr) { // Check if the list is empty
        cout << "The list is empty. Nothing to remove." << endl;
        return;
    }

    Node* current = head;
    Node* prev = nullptr;

    // Case 1: The list contains only one node
    if (head->value == targetValue && head->nextNode == head) {
        delete head;
        head = nullptr;
        return;
    }

    // Case 2: The target node is the head node
    if (head->value == targetValue) {
        // Find the last node
        while (current->nextNode != head) {
            current = current->nextNode;
        }
        Node* toDelete = head;
        head = head->nextNode; // Update the head pointer
        current->nextNode = head; // Adjust the last node's link
        delete toDelete;
        return;
    }

    // Case 3: The target node is in the middle or end of the list
    do {
        prev = current;
        current = current->nextNode;
```

```
        if (current->value == targetValue) {
            prev->nextNode = current->nextNode;
            delete current;
            return;
        }
    } while (current != head);

    // If the target  not found
    cout << "Value " << targetValue << " not found in the list." << endl;
}

// Function to add a new node
void addNode(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->value = value;
    if (head == nullptr) {
        head = newNode;
        newNode->nextNode = head;
        return;
    }

    Node* temp = head;
    while (temp->nextNode != head) {
        temp = temp->nextNode;
    }

    temp->nextNode = newNode;
    newNode->nextNode = head;
}

// Function to print the contents
void printList(Node* head) {
    if (head == nullptr) {
        cout << "The list is empty." << endl;
        return;
    }

    Node* temp = head;
    do {
        cout << temp->value << " ";
        temp = temp->nextNode;
```

```
    } while (temp != head);
    cout << endl;
}

// Main function for operations
int main() {
    Node* head = nullptr;

    addNode(head, 10);
    addNode(head, 20);
    addNode(head, 30);
    addNode(head, 40);

    cout << "Initial list: ";
    printList(head);

    // Remove a node by its value
    removeNodeByValue(head, 20);

    cout << "After removing the node with value 20: ";
    printList(head);

    // Attempt to remove a value that does not exist
    removeNodeByValue(head, 50);

    cout << "After attempting to remove a node with value 50: ";
    printList(head);

    return 0;
}
```



4. **How will you delete a node at a specific position in a circular linked list? Write code for it.**

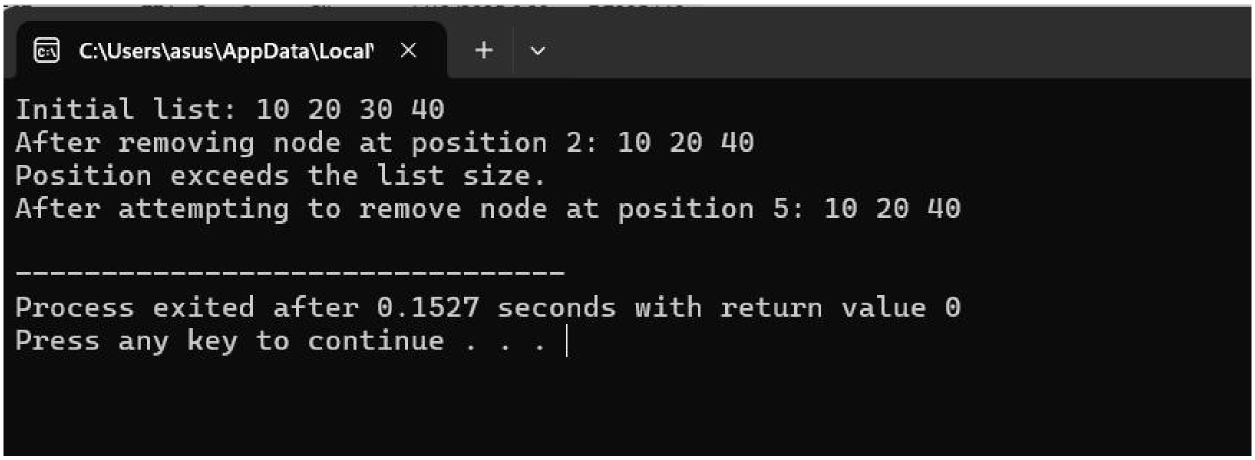
Code:

```
#include <iostream>
using namespace std;

struct Node {
   int value;
   Node* nextNode;
};

// Function to remove a node from specific pos
void removeNodeAt(Node*& head, int position) {
   if (head == nullptr) {
      cout << "The list is empty" << endl;
      return;
   }

   // Handle removal of the head node
   if (position == 0) {
      if (head->nextNode == head) {
         delete head;
         head = nullptr;
      } else {
         Node* last = head;
         while (last->nextNode != head) {
            last = last->nextNode;
         }
```

```
        Node* toDelete = head;
        head = head->nextNode;
        last->nextNode = head;
        delete toDelete;
    }
    return;
  }

  Node* current = head;
  Node* prev = nullptr;
  int currentIndex = 0;

  // Traverse the list to find
  while (current->nextNode != head && currentIndex < position) {
    prev = current;
    current = current->nextNode;
    currentIndex++;
  }

  if (current->nextNode == head && currentIndex < position) { // Out of bounds
    cout << "Position exceeds the list size." << endl;
    return;
  }

  //remove
  prev->nextNode = current->nextNode;
  delete current;
}

// Function to add node at end
void addNode(Node*& head, int value) {
  Node* newNode = new Node();
  newNode->value = value;
  if (head == nullptr) {
    head = newNode;
    newNode->nextNode = head;
    return;
  }

  Node* temp = head;
  while (temp->nextNode != head) {
```

```
        temp = temp->nextNode;
    }

    temp->nextNode = newNode;
    newNode->nextNode = head;
}

// Function to display the contents of the circular linked list
void printList(Node* head) {
    if (head == nullptr) {
        cout << "The list is empty." << endl;
        return;
    }

    Node* temp = head;
    do {
        cout << temp->value << " ";
        temp = temp->nextNode;
    } while (temp != head);
    cout << endl;
}

// Main function
int main() {
    Node* head = nullptr;

    // Add nodes to the list
    addNode(head, 10);
    addNode(head, 20);
    addNode(head, 30);
    addNode(head, 40);

    cout << "Initial list: ";
    printList(head);

    // Remove the node at position 2
    removeNodeAt(head, 2);
    cout << "After removing node at position 2: ";
    printList(head);

    // Attempt to remove a node at an invalid position
```

```
    removeNodeAt(head, 5);
    cout << "After attempting to remove node at position 5: ";
    printList(head);

    return 0;
}
```



```
Initial list: 10 20 30 40
After removing node at position 2: 10 20 40
Position exceeds the list size.
After attempting to remove node at position 5: 10 20 40

--------------------------------
Process exited after 0.1527 seconds with return value 0
Press any key to continue . . .
```

5. **Write a program to show forward traversal after deleting a node in a circular linked list.**

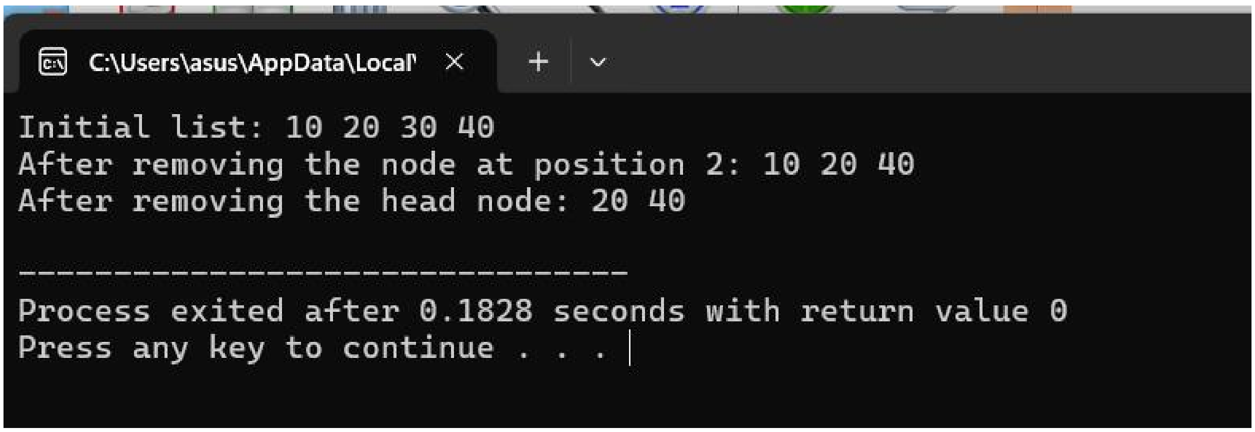
Code:

```
#include <iostream>
using namespace std;

// Definition of a node in a circular linked list
struct Node {
    int value;
    Node* nextNode;
};
void removeNodeAtPosition(Node*& head, int position) {
    if (!head) { // Check if the list is empty
        cout << "The list is empty. Nothing to remove." << endl;
        return;
    }
if (position == 0) {
        // If there's only one node in the list
        if (head->nextNode == head) {
            delete head;
            head = nullptr;
        } else {
            Node* lastNode = head;
```

```
        while (lastNode->nextNode != head) { // Locate the last node
            lastNode = lastNode->nextNode;
        }
        Node* temp = head;
        head = head->nextNode;
        lastNode->nextNode = head;
        delete temp;
    }
    return;
}

Node* current = head;
Node* previous = nullptr;
int index = 0;

// reach the specified position
while (current->nextNode != head && index < position) {
    previous = current;
    current = current->nextNode;
    index++;
}

// If the position is out of bounds
if (current->nextNode == head && index < position) {
    cout << "Invalid position: Out of bounds." << endl;
    return;
}

// Adjust links and delete the node
previous->nextNode = current->nextNode;
delete current;
}

// Function to add a new node to the end
void addNode(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->value = value;
    if (!head) { // Check if the list is empty
        head = newNode;
        newNode->nextNode = head;
        return;
```

```
    }

    Node* current = head;
    while (current->nextNode != head) {
        current = current->nextNode;
    }

    current->nextNode = newNode;
    newNode->nextNode = head; }

// Function to display the circular linked list
void printList(Node* head) {
    if (!head) { // Check if the list is empty
        cout << "The list is empty." << endl;
        return;
    }

    Node* current = head;
    do {
        cout << current->value << " ";
        current = current->nextNode;
    } while (current != head);
    cout << endl;
}

// Main function to test the functionality
int main() {
    Node* head = nullptr;

    // Adding nodes to the list
    addNode(head, 10);
    addNode(head, 20);
    addNode(head, 30);
    addNode(head, 40);

    cout << "Initial list: ";
    printList(head);

    // Remove the node at position 2
    removeNodeAtPosition(head, 2);
    cout << "After removing the node at position 2: ";
```

```
    printList(head);

    // Remove the node at position 0 (head node)
    removeNodeAtPosition(head, 0);
    cout << "After removing the head node: ";
    printList(head);

    return 0;
}
```



Binary Search Tree

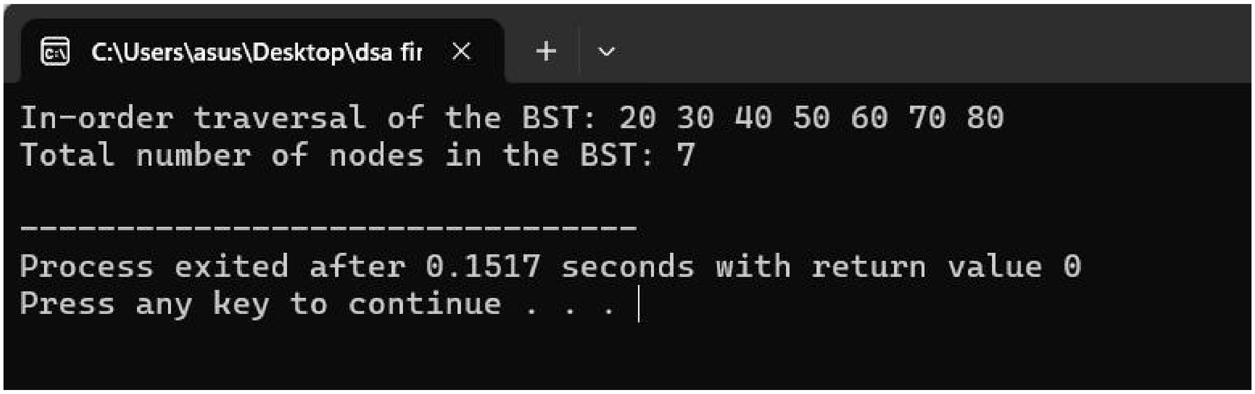
1. **Write a program to count all the nodes in a binary search tree.**
   Code:

```
#include <iostream>

using namespace std;


// Node structure

struct Node {

    int data;

    Node* left;

    Node* right;


    Node(int value) : data(value), left(nullptr), right(nullptr) {}

};
```

```
// Function to insert a node into the BST
Node* insertNode(Node* root, int value) {
    if (!root) return new Node(value);

    if (value < root->data)
        root->left = insertNode(root->left, value);
    else
        root->right = insertNode(root->right, value);

    return root;
}

// Function to count the nodes in the BST
int countNodes(Node* root) {
    if (!root) return 0; // Base case: empty tree

    // Count the current node + left subtree + right subtree
    return 1 + countNodes(root->left) + countNodes(root->right);
}

// Function to display the BST (In-order Traversal)
void inOrderTraversal(Node* root) {
    if (!root) return;

    inOrderTraversal(root->left);
    cout << root->data << " ";
    inOrderTraversal(root->right);
}
```

```
// Main function
int main() {
    Node* root = nullptr;

    // Insert nodes into the BST
    root = insertNode(root, 50);
    root = insertNode(root, 30);
    root = insertNode(root, 70);
    root = insertNode(root, 20);
    root = insertNode(root, 40);
    root = insertNode(root, 60);
    root = insertNode(root, 80);

    // Display the BST
    cout << "In-order traversal of the BST: ";
    inOrderTraversal(root);
    cout << endl;

    // Count the nodes
    int totalNodes = countNodes(root);
    cout << "Total number of nodes in the BST: " << totalNodes << endl;

    return 0;
```

```
}
```

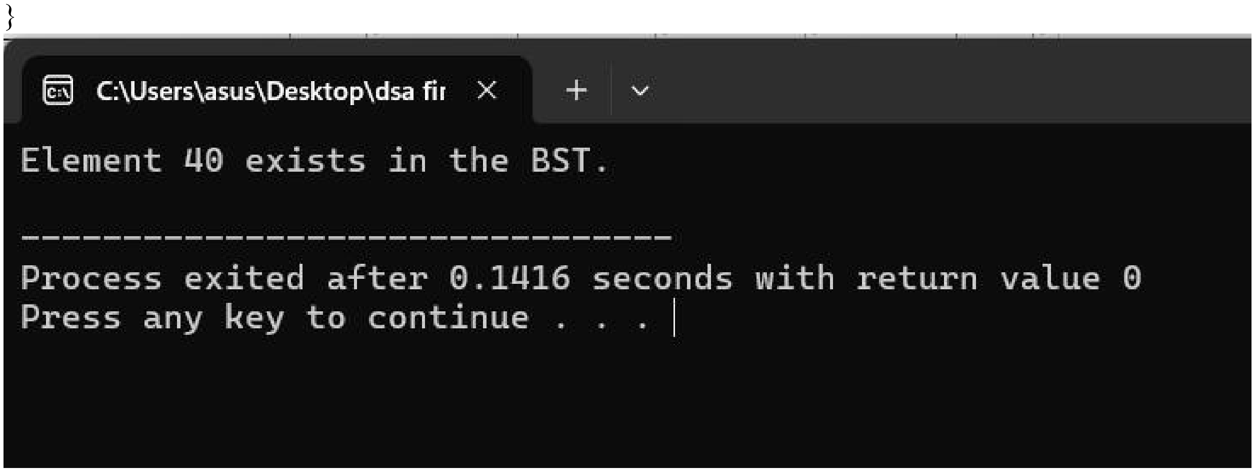


2. **How can you search for a specific value in a binary search tree? Write the code.**
   Code:

```
#include <iostream>
using namespace std;

// Define a node of the binary search tree
struct Node {
    int data;
    Node* left;
    Node* right;

    Node(int value) : data(value), left(nullptr), right(nullptr) {}
};

// Function to insert a node into the binary search tree
Node* insertNode(Node* root, int value) {
    if (root == nullptr) {
        return new Node(value);
    }

    if (value < root->data) {
```

```
        root->left = insertNode(root->left, value);
    } else {
        root->right = insertNode(root->right, value);
    }

    return root;
}

// Function to search for an element in the binary search tree
bool searchNode(Node* root, int value) {
    if (root == nullptr) {
        return false;  // Element not found, root is nullptr
    }

    if (root->data == value) {
        return true;  // Element found
    }

    if (value < root->data) {
        return searchNode(root->left, value);  // Search in left subtree
    } else {
        return searchNode(root->right, value); // Search in right subtree
    }
}

int main() {
    Node* root = nullptr;

    // Insert elements into the binary search tree
    root = insertNode(root, 50);
```

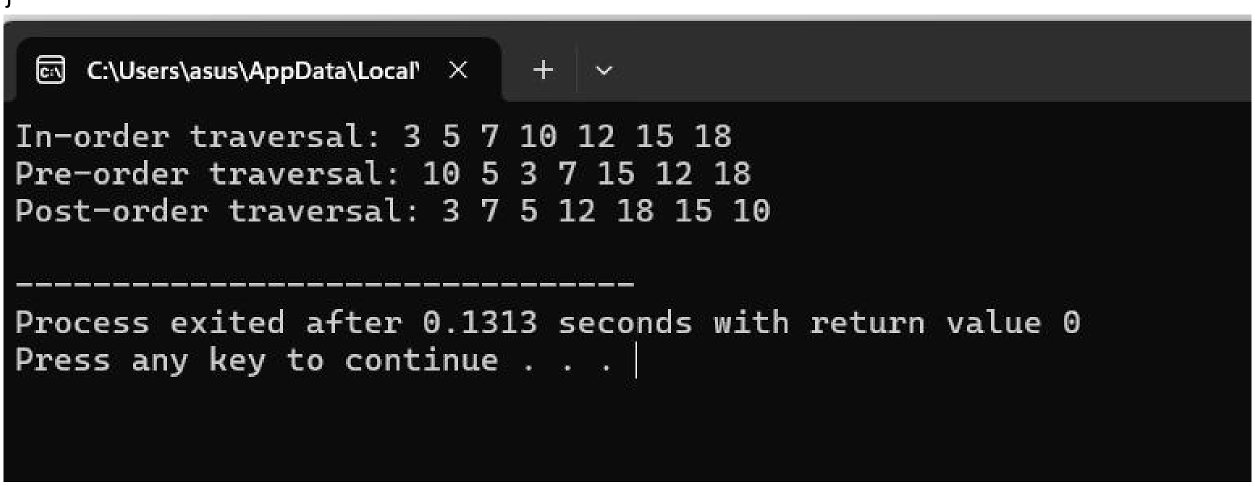
```
    root = insertNode(root, 30);
    root = insertNode(root, 20);
    root = insertNode(root, 40);
    root = insertNode(root, 70);
    root = insertNode(root, 60);
    root = insertNode(root, 80);

    // Search for an element
    int searchValue = 40;
    bool result = searchNode(root, searchValue);

    if (result) {
        cout << "Element " << searchValue << " exists in the BST." << endl;
    } else {
        cout << "Element " << searchValue << " does not exist in the BST." << endl;
    }

    return 0;
}
```



3. **Write code to traverse a binary search tree in in-order, pre-order, and post order.**
   Code:

```
#include <iostream>
using namespace std;

// Define a TreeNode structure for the binary tree
struct TreeNode {
    int value;
    TreeNode* left;
    TreeNode* right;

    TreeNode(int val) {
        value = val;
        left = nullptr;
        right = nullptr;
    }
};

// In-order Traversal (Left, Root, Right)
void inorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    inorderTraversal(root->left);
    cout << root->value << " ";
    inorderTraversal(root->right);
}

// Pre-order Traversal (Root, Left, Right)
void preorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    cout << root->value << " ";
    preorderTraversal(root->left);
    preorderTraversal(root->right);
}

// Post-order Traversal (Left, Right, Root)
void postorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    postorderTraversal(root->left);
    postorderTraversal(root->right);
    cout << root->value << " ";
}

// Main function to test the traversal functions
```

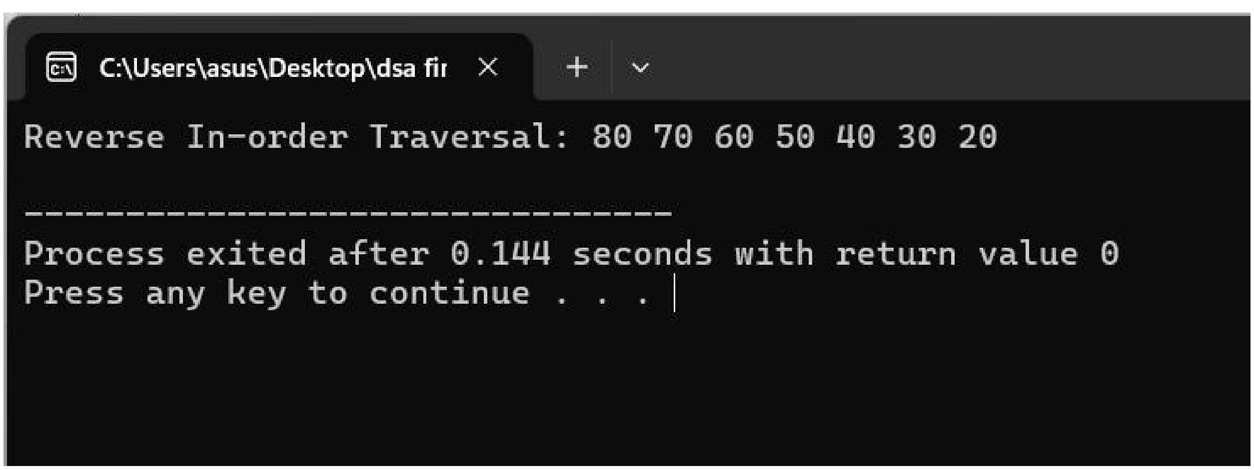
```
int main() {
   TreeNode* root = new TreeNode(10);
   root->left = new TreeNode(5);
   root->right = new TreeNode(15);
   root->left->left = new TreeNode(3);
   root->left->right = new TreeNode(7);
   root->right->left = new TreeNode(12);
   root->right->right = new TreeNode(18);

   // In-order Traversal
   cout << "In-order traversal: ";
   inorderTraversal(root);
   cout << endl;

   // Pre-order Traversal
   cout << "Pre-order traversal: ";
   preorderTraversal(root);
   cout << endl;

   // Post-order Traversal
   cout << "Post-order traversal: ";
   postorderTraversal(root);
   cout << endl;

   return 0;
}
```



4. **How will you write reverse in-order traversal for a binary search tree? Show it in code.**
   Code:

```
#include <iostream>
using namespace std;

// Node structure
struct Node {
    int data;
    Node* left;
    Node* right;

    Node(int value) : data(value), left(nullptr), right(nullptr) {}
};

// Function to insert a node into the BST
Node* insertNode(Node* root, int value) {
    if (!root) return new Node(value);

    if (value < root->data)
        root->left = insertNode(root->left, value);
    else
        root->right = insertNode(root->right, value);

    return root;
}

// Reverse In-order Traversal: Right -> Root -> Left
void reverseInOrderTraversal(Node* root) {
    if (!root) return;
    reverseInOrderTraversal(root->right);  // Visit right subtree
    cout << root->data << " ";             // Visit root
    reverseInOrderTraversal(root->left);   // Visit left subtree
```

```
}

// Main function
int main() {
    Node* root = nullptr;

    // Insert nodes into the BST
    root = insertNode(root, 50);
    root = insertNode(root, 30);
    root = insertNode(root, 70);
    root = insertNode(root, 20);
    root = insertNode(root, 40);
    root = insertNode(root, 60);
    root = insertNode(root, 80);

    // Perform and display the reverse in-order traversal
    cout << "Reverse In-order Traversal: ";
    reverseInOrderTraversal(root);
    cout << endl;

    return 0;
}
```

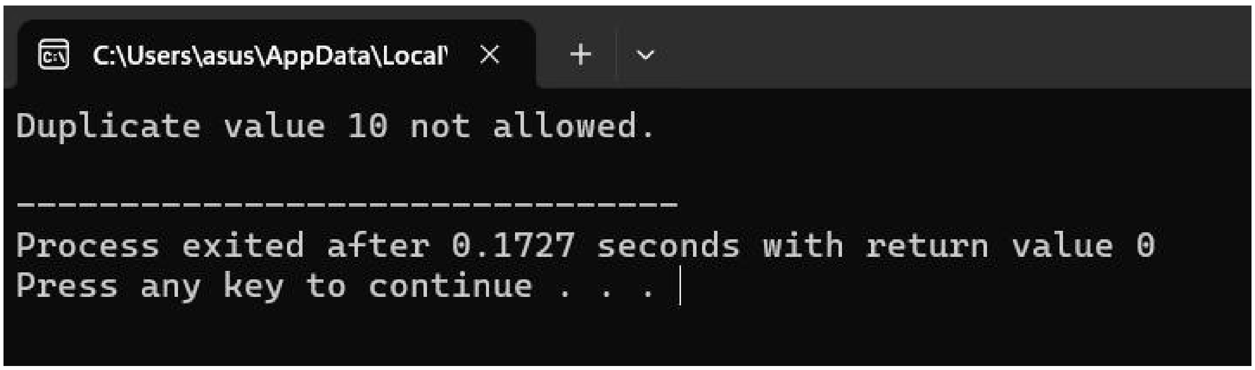


5. **Write a program to check if there are duplicate values in a binary search tree.**

Code:

```
#include <iostream>
using namespace std;

// Node structure
struct Node {
    int data;
    Node* left;
    Node* right;
    Node(int val) {
        data = val;
        left = NULL;
        right = NULL;
    }
};

// Function to insert a value (with duplicate check)
Node* insert(Node* root, int val) {
    if (root == NULL) {
        return new Node(val);
    }
    if (val < root->data) {
        root->left = insert(root->left, val);
    } else if (val > root->data) {
        root->right = insert(root->right, val);
    } else {
        cout << "Duplicate value " << val << " not allowed." << endl;
    }
    return root;
}

// Main function to test duplication handling
int main() {
    Node* root = NULL;

    root = insert(root, 10);
    root = insert(root, 5);
```

```
    root = insert(root, 15);
    root = insert(root, 3);
    root = insert(root, 7);
    root = insert(root, 12);
    root = insert(root, 10); // Duplicate Values
    root = insert(root, 18);


    return 0;
}
```



6. **How can you delete a node from a binary search tree? Write code for deleting a leaf, a node with one child, and a node with two children. code:**

```
#include <iostream>
using namespace std;

// Node structure
struct Node {
    int data;
    Node* left;
    Node* right;

    Node(int value) : data(value), left(nullptr), right(nullptr) {}
};

// Function to insert a node into the BST
```

```
Node* insertNode(Node* root, int value) {
    if (!root) return new Node(value);

    if (value < root->data)
        root->left = insertNode(root->left, value);
    else
        root->right = insertNode(root->right, value);

    return root;
}

// Function to find the minimum node in a subtree (used for finding in-order successor)
Node* findMin(Node* root) {
    while (root && root->left)
        root = root->left;
    return root;
}

// Function to delete a node in a BST
Node* deleteNode(Node* root, int value) {
    if (!root) return root;

    // If value to be deleted is smaller than root's value, it lies in the left subtree
    if (value < root->data)
        root->left = deleteNode(root->left, value);

    // If value to be deleted is greater than root's value, it lies in the right subtree
    else if (value > root->data)
        root->right = deleteNode(root->right, value);
```

```
    // If value is the same as root's value, this is the node to be deleted
    else {
        // Case 1: Node has no children (leaf node)
        if (!root->left && !root->right) {
            delete root;
            root = nullptr;
        }
        // Case 2: Node has one child
        else if (!root->left) {
            Node* temp = root;
            root = root->right;
            delete temp;
        } else if (!root->right) {
            Node* temp = root;
            root = root->left;
            delete temp;
        }
        // Case 3: Node has two children
        else {
            Node* temp = findMin(root->right); // Get the in-order successor (smallest in right subtree)
            root->data = temp->data; // Replace root's value with in-order successor's value
            root->right = deleteNode(root->right, temp->data); // Delete the in-order successor
        }
    }

    return root;
}

// Function to perform in-order traversal
void inOrderTraversal(Node* root) {
```

```
    if (!root) return;
    inOrderTraversal(root->left);
    cout << root->data << " ";
    inOrderTraversal(root->right);
}

// Main function
int main() {
    Node* root = nullptr;

    // Insert nodes into the BST
    root = insertNode(root, 50);
    root = insertNode(root, 30);
    root = insertNode(root, 70);
    root = insertNode(root, 20);
    root = insertNode(root, 40);
    root = insertNode(root, 60);
    root = insertNode(root, 80);

    cout << "In-order traversal of the BST before deletion: ";
    inOrderTraversal(root);
    cout << endl;

    // Delete nodes and perform in-order traversal after each deletion

    // Deleting a leaf node (e.g., 20)
    root = deleteNode(root, 20);
    cout << "In-order traversal after deleting leaf node 20: ";
    inOrderTraversal(root);
    cout << endl;
```

```
    // Deleting a node with one child (e.g., 30)
    root = deleteNode(root, 30);
    cout << "In-order traversal after deleting node with one child (30): ";
    inOrderTraversal(root);
    cout << endl;

    // Deleting a node with two children (e.g., 50)
    root = deleteNode(root, 50);
    cout << "In-order traversal after deleting node with two children (50): ";
    inOrderTraversal(root);
    cout << endl;

    return 0;
}
```