

## Assignment 1: Civil Engineering Case Study – Beam Deflection

### Step 1: Problem Identification and Statement

Create a software program that determines the vertical deflection of a simply supported beam at a specific location when it is subjected to a point load. The program will allow users to input beam parameters (moment of inertia, Young's modulus, applied load, beam length, and load position). Based on the input data, calculate the beam deflection. Before the calculation is performed, it will allow the user to change the values. Then, the program will display a menu-based system to make the options easier for users to navigate. The program will verify that the input values are validated since no unrealistic or negative numbers should be accepted. The program allows the user to repeat any of these operations or quit the program.

### Step 2: Gathering Information and Input/Output Description

#### Relevant Information:

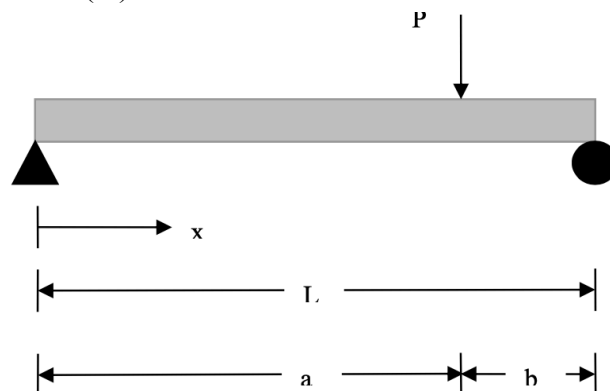
A beam simply supported at both ends is loaded as shown in the figure below. Under the load, the beam will deflect vertically. This vertical deflection of the beam,  $V$ , will vary along the length of the beam from  $x = 0$  to  $L$ . This deflection affects the safety and functionality of structures, making it important in civil engineering. And it is given by

$$V = \frac{Pb}{6EI} [(-L^2 + b^2)x + x^3], 0 \leq x \leq a$$

$$V = \frac{Pb}{6EI} [(-L^2 + b^2)x + x^3 - \frac{L}{b}(x-a)^3], a < x \leq L$$

Where:

- $x$ : the distance from the left end (m)
- $P$ : the load,  $L$  is the length of the beam (N)
- $a$ : the location where the load  $P$  is applied (m)
- $E$ : the Young's modulus of the beam material (Pa)
- $I$ : the second moment of area ( $\text{m}^4$ )
- $V$ : Vertical deflection (m)



### The formulas and how the beam deflection is calculated:

To calculate the beam deflection we use different formulas depending on whether  $0 \leq x \leq a$  or  $a < x \leq L$

**When :**

$$0 \leq x \leq a$$

We use this formula to calculate the deflection :

$$V = \frac{Pb}{6EIL} [(-L^2 + b^2)x + x^3]$$

Note that b is equal to L-a

**And when :**  $a < x \leq L$

We use this formula :

$$V = \frac{Pb}{6EIL} [(-L^2 + b^2)x + x^3 - \frac{L}{b}(x-a)^3],$$

The vertical movement of a beam brought on by applied loads is known as beam deflection. The deflection of a simply supported beam under a point load is computed by this program. The beam length (L), applied load (P), load location (a), Young's modulus (E), and second moment of area (I) all affect the deflection equation. Using an interactive system, this program asks the user for these parameters and calculates the deflection at a given point (x). By verifying user inputs and displaying error messages for values that are not valid, it guarantees correctness.

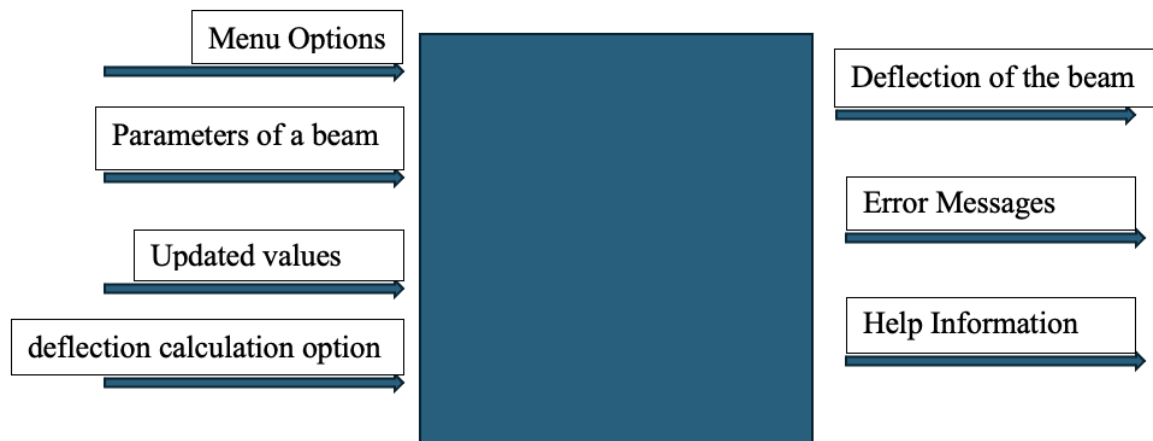
### Input/output Description (I/O Diagram) :

Input:

1. Menu Options: option of calculating, helping, or exiting the program.
2. Parameters of the beam: x the distance from the left end, P the load, L the length of the beam, a the location where the load P is applied, E the Young's modulus of the beam material, and I the second moment of area
3. Updated values: A new value is entered by the user when they want to change a parameter.
4. Deflection Calculation: calculation of the beam deflection if the user selects option 7.

Output:

1. Deflection of the beam: V as an output at point x
2. Error messages: For invalid inputs or menu selections
3. Help Information: Displaying a description about what the program does.

**I/O Diagram:****Step 3: Test Cases and algorithm*****Test Case 1: Option (1): calculating the beam deflection with initial values.***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at x = 2.5 is -0.105794

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

***Test Case 2: Option (1): calculating the beam deflection while changing the beam length L***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]

- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 2

Please enter the Length of the Beam (current: 5): 10

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 10 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at  $x = 2.5$  is -0.919596

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

***Test Case 3: Option (1): calculating the beam deflection while changing the load location a***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 4

Please enter the Location where the load is applied (current: 3): 4

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 4 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at  $x = 2.5$  is -0.0298394

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

***Test Case 4: calculating the beam deflection while changing x to 4 to test the 2nd formula***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 1

Please enter the Deflection Calculation Point (current: 2.5): 4

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 4 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at  $x = 4$  is -0.0434028

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

***Test Case 5: calculating the beam deflection while loading at the center***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 2

Please enter the Length of the Beam (current: 5): 2.5

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 2.5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at  $x = 2.5$  is 0.0976562

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

***Test Case 6: calculating the beam deflection while changing the load P***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 3

Please enter the Load (current: 20000): 10000

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]

- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 10000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at  $x = 2.5$  is -0.0528971

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

### ***Test Case 7: calculating the beam deflection while changing Young's Modulus E***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 5

Please enter Young's Modulus of the beam material (current: 3e+07): 4e+07

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 4e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at  $x = 2.5$  is -0.0793457

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

### ***Test Case 8: calculating the beam deflection while changing the Second Moment of Area I***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]
- 7) Calculate beam deflection

Enter option: 6

Please enter the Second Moment of Area (current: 0.0256): 0.255

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.255 ]
- 7) Calculate beam deflection

Enter option: 7

The Beam deflection at  $x = 2.5$  is -0.0106209

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option:

### ***Test Case 9: handling invalid input***

#### ***For main menu :***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: -1

This option is invalid! Select 1, 2, or 3 please: 8

This option is invalid! Select 1, 2, or 3 please:

#### ***For secondary menu :***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 1

Beam Parameters Menu:

- 1) Calculation Point (x) [Current: 2.5 ]
- 2) Length of the Beam (L) [Current: 5 ]
- 3) Load (P) [Current: 20000 ]
- 4) Location where the load is applied (a) [Current: 3 ]
- 5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
- 6) Second Moment of Area (I) [Current: 0.0256 ]



7) Calculate beam deflection

Enter option: 9

This option is invalid! Please enter a valid option between 1 and 7: -2

This option is invalid! Please enter a valid option between 1 and 7:

### ***For Beam parameters :***

Main Menu:

1) Calculate the beam deflection

2) Help

3) Exit

Enter option: 1

Beam Parameters Menu:

1) Calculation Point (x) [Current: 2.5 ]

2) Length of the Beam (L) [Current: 5 ]

3) Load (P) [Current: 20000 ]

4) Location where the load is applied (a) [Current: 3 ]

5) Young's Modulus of the beam material (E) [Current: 3e+07 ]

6) Second Moment of Area (I) [Current: 0.0256 ]

7) Calculate beam deflection

Enter option: 4

Please enter the Location where the load is applied (current: 3): -3

Invalid input. Ensure values are positive and valid: 400

Invalid input. Ensure values are positive and valid: 7

Invalid input. Ensure values are positive and valid: 5

Beam Parameters Menu:

1) Calculation Point (x) [Current: 2.5 ]

2) Length of the Beam (L) [Current: 5 ]

3) Load (P) [Current: 20000 ]

4) Location where the load is applied (a) [Current: 5 ]

5) Young's Modulus of the beam material (E) [Current: 3e+07 ]

6) Second Moment of Area (I) [Current: 0.0256 ]

7) Calculate beam deflection

Enter option:

### ***Test Case 10: Help Option***

Main Menu:

1) Calculate the beam deflection

2) Help

3) Exit

Enter option: 2

Help Menu:

This program computes a simply supported beam's deflection.

Beam parameters can be updated before any computations.

Select Option 1 to input the parameters before computing deflection.

To see the results, select 'Compute beam deflection' from the secondary menu.

Select Option 3 from the main menu to exit the program.

Back to the Main Menu.

Main Menu:

1) Calculate the beam deflection

2) Help

3) Exit

Enter option:

### ***Test Case 11: Exit Option***

Main Menu:

- 1) Calculate the beam deflection
- 2) Help
- 3) Exit

Enter option: 3

You have chosen to quit. Exiting the program.

Program ended with exit code: 0

### ***Algorithm Design:***

*Program Memory:*

*Assign 2.5 to x*

*Assign 5 to L*

*Assign 20000 to P*

*Assign 3 to a*

*Assign 30e6 to E*

*Assign 0.0256 to I*

*While true Do*

*Print "Main Menu", Newline*

*Print "1) Calculate the beam deflection", Newline*

*Print "2) Help", Newline*

*Print "3) Exit", Newline*

*Ask user to select option*

*Read value into option*

*(validate choice)*

*While option < 1 OR option > 3 Do*

*Print "This option is invalid! Select 1, 2, or 3 please: "*

*Read value into option*

*If option == 1 Then ( Enter Beam Parameters)*

*While true Do*

*Print "Beam Parameters Menu", Newline*

*Print "1) Calculation Point (x) [Current: ", x, "]", Newline*

*Print "2) Length of the Beam (L) [Current: ", L, "]", Newline*

*Print "3) Load (P) [Current: ", P, "]", Newline*

```

Print "4) Location where the load is applied (a) [Current: ", a, "]", Newline
Print "5) Young's Modulus (E) [Current: ", E, "]", Newline
Print "6) Second Moment of Area (I) [Current: ", I, "]", Newline
Print "7) Calculate beam deflection", Newline
( Ask user to select sub_option)
Read sub_option

(Validate sub-option input)
While sub_option < 1 OR sub_option > 7 Do
    Print "This option is invalid! Please enter a valid option between 1 and
7"

    Read sub_option

( If user wants to update beam parameters)
If sub_option >= 1 AND sub_option <= 6 Then

    (ask user while displaying current parameter value)
    If sub_option == 1 Then
        Print "Please enter the Deflection Calculation Point (current: ",
x, "): ", Newline

    Else If sub_option == 2 Then
        Print "Please enter the Length of the Beam (current: ", L, "): ",
Newline

    Else If sub_option == 3 Then
        Print "Please enter the Load (current: ", P, "): ", Newline
    Else If sub_option == 4 Then
        Print "Please enter the Location where the load is applied
(current: ", a, "): ", Newline

    Else If sub_option == 5 Then
        Print "Please enter Young's Modulus of the beam material
(current: ", E, "): ", Newline

    Else If sub_option == 6 Then
        Print "Please enter the Second Moment of Area (current: ", I, "):
", Newline

    Read updated_value

```

OR

( Invalid input for new parameters)  
 While updated\_value < 0 OR  
 (sub\_option == 1 AND (updated\_value <= 0 OR updated\_value > L))

(sub\_option == 2 AND updated\_value <= 0) OR  
 (sub\_option == 3 AND updated\_value <= 0) OR  
 (sub\_option == 4 AND (updated\_value <= 0 OR updated\_value > L))

OR

(sub\_option == 5 AND updated\_value <= 0) OR  
 (sub\_option == 6 AND updated\_value <= 0) DO  
 Print "Invalid input. Ensure values are positive and valid "  
 Read updated\_value

( Update parameters)  
 If sub\_option == 1 Then  
 $x = \text{updated\_value}$   
 Else If sub\_option == 2 Then  
 $L = \text{updated\_value}$   
 Else If sub\_option == 3 Then  
 $P = \text{updated\_value}$   
 Else If sub\_option == 4 Then  
 $a = \text{updated\_value}$   
 Else If sub\_option == 5 Then  
 $E = \text{updated\_value}$   
 Else If sub\_option == 6 Then  
 $I = \text{updated\_value}$

( If user selects to calculate the beam deflection)  
 Else if sub\_option == 7 Then  
 )

If  $x < a$  Then  
 Assign  $(-P * x * (L^2 - a^2 - x^2)) / (6 * E * I)$  to  $V$   
 Otherwise  
 Assign  $(-P * (L - a) * (L^2 - x^2 - (L - a)^2)) / (6 * E * I)$  to  $V$

*Print "The Beam deflection at  $x =$  ",  $x$ , " is ",  $V$ , " m"*  
*BREAK ( Back to main menu)*

*Else If option == 2 Then ( Print Help Menu)*

*Print "Help Menu"*

*Print "This program computes a simply supported beam's deflection.", Newline*

*Print "Beam parameters can be updated before any computations.", Newline*

*Print "Select Option 1 to input the parameters before computing deflection.", Newline*

*Print "To see the results, select 'Compute beam deflection' from the secondary menu.",  
 Newline*

*Print "Select Option 3 from the main menu to exit the program.", Newline*

*Print "Returning to Main Menu..."*

*Else If option == 3 Then ( Exit Program)*

*Print "You have chosen to quit. Exiting the program.", Newline*

### Step 4: Code or implementation

```
#include <iostream>
#include <cmath>
using namespace std;
int main() {
    // Set the beam parameters to their initial default values.
    double x = 2.5, L = 5, P = 20000, a = 3, E = 30e6, I = 0.0256;
    int option;
    // Main menu loop
    while (true) {
        // main option menu
        cout << "Main Menu:\n";
        cout << "1) Calculate the beam deflection\n";
        cout << "2) Help\n";
        cout << "3) Exit\n";
        cout << "Enter option: ";
        cin >> option;
        // Confirm the main menu selection
        while (option < 1 || option > 3) {
            cout << "This option is invalid! Select 1, 2, or 3 please: ";
            cin >> option;
        }
        if (option == 1) { // menu for input beam parameters
            int sub_option;
            while (true) {
                cout << "Beam Parameters Menu:\n";
                cout << "1) Calculation Point (x) [Current: " << x << " ]\n";
                cout << "2) Length of the Beam (L) [Current: " << L << " ]\n";
                cout << "3) Load (P) [Current: " << P << " ]\n";
                cout << "4) Location where the load is applied (a) [Current: " << a << " ]\n";
                cout << "5) Young's Modulus of the beam material (E) [Current: " << E << " ]\n";
                cout << "6) Second Moment of Area (I) [Current: " << I << " ]\n";
                cout << "7) Calculate beam deflection\n";
                cout << "Enter option: ";
                cin >> sub_option;
                // Invalid values for secondary menu
                while (sub_option < 1 || sub_option > 7) {
                    cout << "This option is invalid! Please enter a valid option between 1 and 7: ";
                    cin >> sub_option;
                }
                // updating input beam parameters
                if (sub_option >= 1 && sub_option <= 6) {
                    double updated_value; // input for the new parameter

                    // Show the current value in the prompt message based on the chosen parameter
                    if (sub_option == 1)
                        cout << "Please enter the Deflection Calculation Point (current: " << x << "): ";
                    else if (sub_option == 2)
                        cout << "Please enter the Length of the Beam (current: " << L << "): ";
                    else if (sub_option == 3)
                        cout << "Please enter the Load (current: " << P << "): ";
                    else if (sub_option == 4)
                        cout << "Please enter the Location where the load is applied (current: " << a << "): ";
                    else if (sub_option == 5)
                        cout << "Please enter Young's Modulus of the beam material (current: " << E << "): ";
```

```

    else if (sub_option == 6)
        cout << "Please enter the Second Moment of Area (current: " << I << "): ";
    cin >> updated_value;
    // Invalid input for new parameters
    while (updated_value < 0 ||
        (sub_option == 1 && (updated_value <= 0 || updated_value > L)) || // x can't be negative and larger than L
        (sub_option == 2 && updated_value <= 0) || // L can't be negative
        (sub_option == 3 && updated_value <= 0) || // P can't be negative
        (sub_option == 4 && (updated_value <= 0 || updated_value > L)) || // a can't be negative and larger than L
        (sub_option == 6 && updated_value <= 0)) // I can't be negative
    {
        cout << "Invalid input. Ensure values are positive and valid: ";
        cin >> updated_value;
    }
    // Assign the new parameters
    if (sub_option == 1) x = updated_value;
    else if (sub_option == 2) L = updated_value;
    else if (sub_option == 3) P = updated_value;
    else if (sub_option == 4) a = updated_value;
    else if (sub_option == 5) E = updated_value;
    else if (sub_option == 6) I = updated_value;
}
// Compute beam deflection
if (sub_option == 7) {
    double V;
    if (x < a) {
        V = (-P * x * (L * L - a * a - x * x)) / (6 * E * I);
    } else {
        V = (-P * (L - a) * (L * L - x * x - (L - a) * (L - a))) / (6 * E * I);
    }
    cout << "The Beam deflection at x = " << x << " is " << V << "\n";
    break; // back to main menu
}
}
}
else if (option == 2) { // displaying help menu
    cout << "Help Menu:\n";
    cout << "This program computes a simply supported beam's deflection.\n";
    cout << "Beam parameters can be updated before any computations.\n";
    cout << "Select Option 1 to input the parameters before computing deflection.\n";
    cout << "To see the results, select 'Compute beam deflection' from the secondary menu.\n";
    cout << "Select Option 3 from the main menu to exit the program.\n";
    cout << " Back to the Main Menu.\n";
}
else if (option == 3) { // option to exit program
    cout << "You have chosen to quit. Exiting the program. \n";
    return(0);
}
}
}
}

```

### Step 5: Test and Verification

To test if the program is successful and working, we will run the program and try each test case

**Test Case 1: Option (1): calculating the beam deflection with initial values.**

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 2.5 is -0.105794
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: |

```

No issues

**Test Case 2: Option (1): calculating the beam deflection while changing the beam length  $L$**

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 2
Please enter the Length of the Beam (current: 5): 10
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 10 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 2.5 is -0.919596
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: |

```

No issues

**Test Case 3: Option (1): calculating the beam deflection while changing the load location  $a$**



```

Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 4
Please enter the Location where the load is applied (current: 3): 4
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 4 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 2.5 is -0.0298394
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option:

```

No issues

#### ***Test Case 4: calculating the beam deflection while changing x to 4 to test the 2nd formula***

```

Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 1
Please enter the Deflection Calculation Point (current: 2.5): 4
Beam Parameters Menu:
1) Calculation Point (x) [Current: 4 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 4 is -0.0434028
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: |

```

No issues

### *Test Case 5: calculating the beam deflection while loading at the center*

```

Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 2
Please enter the Length of the Beam (current: 5): 2.5
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 2.5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 2.5 is 0.0976562
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: |

```

No issues

### *Test Case 6: calculating the beam deflection while changing the load P*

```

Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 3
Please enter the Load (current: 20000): 10000
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 10000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 2.5 is -0.0528971
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option:

```

No issues

### *Test Case 7: calculating the beam deflection while changing Young's Modulus E*

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 5
Please enter Young's Modulus of the beam material (current: 3e+07): 4e+07
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 4e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 2.5 is -0.0793457
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option:

```

No issues

### *Test Case 8: calculating the beam deflection while changing the Second Moment of Area I*

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 6
Please enter the Second Moment of Area (current: 0.0256): 0.255
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.255 ]
7) Calculate beam deflection
Enter option: 7
The Beam deflection at x = 2.5 is -0.0106209
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: |

```

No issues

### ***Test Case 9: handling invalid input***

#### ***For main menu :***

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: -1
This option is invalid! Select 1, 2, or 3 please: 8
This option is invalid! Select 1, 2, or 3 please: |

```

No issues

#### ***For secondary menu :***

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 9
This option is invalid! Please enter a valid option between 1 and 7: -2
This option is invalid! Please enter a valid option between 1 and 7:

```

No issues

#### ***For Beam parameters :***

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 1
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 3 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: 4
Please enter the Location where the load is applied (current: 3): -3
Invalid input. Ensure values are positive and valid: 400
Invalid input. Ensure values are positive and valid: 7
Invalid input. Ensure values are positive and valid: 5
Beam Parameters Menu:
1) Calculation Point (x) [Current: 2.5 ]
2) Length of the Beam (L) [Current: 5 ]
3) Load (P) [Current: 20000 ]
4) Location where the load is applied (a) [Current: 5 ]
5) Young's Modulus of the beam material (E) [Current: 3e+07 ]
6) Second Moment of Area (I) [Current: 0.0256 ]
7) Calculate beam deflection
Enter option: |

```

No issues

### ***Test Case 10: Help Option***

```

cpe_assignment1 Line: 18 Col: 23
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 2
Help Menu:
This program computes a simply supported beam's deflection.
Beam parameters can be updated before any computations.
Select Option 1 to input the parameters before computing deflection.
To see the results, select 'Compute beam deflection' from the secondary menu.
Select Option 3 from the main menu to exit the program.
Back to the Main Menu.
Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: |

```

No issues

### ***Test Case 11: Exit Option***

```

Main Menu:
1) Calculate the beam deflection
2) Help
3) Exit
Enter option: 3
You have chosen to quit. Exiting the program.
Program ended with exit code: 0

```

No issues

### ***User guide:***

This program calculates a simply supported beam's deflection when subjected to a point load. The user can calculate deflection, enter beam and load parameters, and change them as necessary. Three choices are available on the main menu: (1) Calculate the beam's deflection, (2) Provide help, and (3) exit. By choosing option (1), values like beam length (L), load (P), and material properties (E, I) can be changed. After changing the parameters, choosing option (7) calculates and shows the deflection; downward deflection is indicated by negative values. By validating inputs, the program avoids invalid values like negative lengths or improper load placements. Following calculations, users have the option to depart using option (3) or return to the main menu. This guide guarantees effective software use for precise beam deflection analysis.