ME212 COURSE PROJECT

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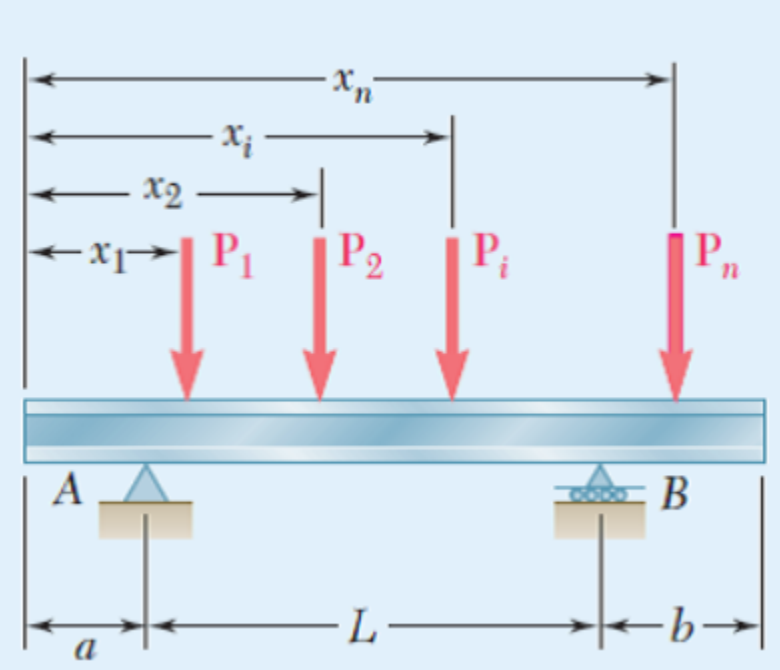
BRANCH: CHEMICAL ENGINEERING

PROBLEM STATEMENT:

Several concentrated loads P_i , (i = 1, 2, . . . , n) can be applied to a beam as shown. Write a computer program that can be used to calculate the shear, bending moment, and normal stress at any point of the beam for a given loading of the beam and a given value of its section modulus.



SOLUTION:

Step 1) Using moment equilibrium at support A we can calculate the reaction forces at point A and B.

$\sum M_A = 0$

⇨ $R_B L - \sum P_i(x_i - a) = 0$

Here, subscript i denotes different loads and varies as 1, 2, 3….

⇨ $R_B = \sum P_i(x_i - a)/L$

Using force equilibrium in vertical direction:

$\sum F_Y = 0$

⇨ $R_A = \sum P_i - R_B$

Step 2) We compute the step function for different conditions:

If x>=a, stepA=1, else stepA=0.

If x>=a+L, stepB=1, else stepB=0.

If x>=xi, stepI=1, else stepI=0. (stepI is variable to define ith step function.)

Step 3) Calculate shear force (V_x), bending moment (M_x) and normal stress (σ_x) :

From force equilibrium in vertical direction, we can calculate shear force (V_x) at a section distance x along the beam as,

$\mathbf{V_x = R_A\ (stepA) + R_B\ (stepB) - \sum P_i(stepI)}$

Also, from moment equilibrium, net moment (M_x) at a section at a distance x along the beam is expressed as,

$\mathbf{M_x = R_A(x-a)(stepA) + R_B(x-a-L)(stepB) - \sum P_i(x-x_i)(stepI)}$

We can calculate the bending stress (σ_x) at any distance x along the beam by,

$\mathbf{\sigma_x = M_x / S}$

C++ code to solve the problem:

```
#include <iostream>

using namespace std;

int main(){

        int n; //number of point loads

        float a; //distance between support A and left end of the beam

        float b; //distance between support B and right end of the beam

        float l; //span of the beam

        float s; //section modulus of the beam

   cout<<"INPUT :"<<endl;

   cout<<endl;

        cout<<"Enter the number of point loads :";

        cin>>n;

        cout<<endl;

        cout<<"Distance between support A and left end of the beam [in mm] :";

        cin>>a;

        cout<<endl;

        cout<<"Distance between support B and right end of the beam [in mm] :";

        cin>>b;

        cout<<endl;

        cout<<"Span of the beam [in mm] :";

        cin>>l;

        cout<<endl;

        cout<<"Section modulus of the beam [in mm^3] :";

        cin>>s;
```

```
        cout<<endl;
        float loads[n]; // array to store the value of each load
        float dist_of_loads[n]; // array to store the distance of each load from left end
        float sumP=0; //summation of all loads
        float reactionB=0; //reaction forceat end A
        float reactionA=0; //reaction force at end B
        for(int i=1;i<=n;i++){
                cout<<"Enter the point load p"<<i<<" [in N] :";
                cin>>loads[i];
                cout<<"Enter the distance x"<<i<<" of load p"<<i<<" from left end [in mm]
:";
                cin>>dist_of_loads[i];
                cout<<endl;
                sumP=sumP+ loads[i];
                reactionB=reactionB + (loads[i]*(dist_of_loads[i]-a))/l;
        }
        reactionA=sumP-reactionB;
        int m; // number of cross sections at which stress is to be found
        cout<<"Enter the number of Cross Sections at which stress is to be found :";
        cin>>m;
        cout<<endl;
        float dist[m]; //array of distances of cross sections at which stress is to be
calculated
        for(int j=1;j<=m;j++){
                cout<<"Enter the distance of Cross section "<<j<<" [in mm] :";
                cin>>dist[j];
                cout<<endl;
```

```
        }
        cout<<"OUTPUT :"<<endl;
cout<<endl;
cout<<"Reaction force at A [in kN] :"<<reactionA/1000<<endl;
        cout<<"Reaction force at b [in kN] :"<<reactionB/1000<<endl;
        cout<<endl;
        for(int k=1;k<=m;k++){
                float c=0,d=0;
                int stepA,stepB,stepl;
                if(dist[k]>=a){
                        stepA=1;
                }
                else
                        stepA=0;
                if(dist[k]>=a+l){
                        stepB=1;
                }
                else
                        stepB=0;
                float V; //shear stress
                float M; // bending moment
                float sigma; // normal stress
                for(int i=1;i<=n;i++){
                        if(dist[k]>=dist_of_loads[i]){
                                stepl=1;
                        }
```

```
                else
                        stepl=0;
                c=c+loads[i]*stepl;
                d=d+loads[i]*(dist[k]-dist_of_loads[i])*stepl;
                V=reactionA*stepA + reactionB*stepB -c;
                M=reactionA*(dist[k]-a)*stepA +reactionB*(dist[k]-a-l)*stepB - d;
                sigma=M/s;
                if(dist[k]>l){
                        V=M=sigma=0;
                } }
        cout<<"At x="<<dist[k]/1000<<" m :"<<endl;
        cout<<"(1) Shear Stress [in kN] :"<<V/1000<<endl;
        cout<<"(2) Bending Moment [in kN-m] :"<<M/1000000<<endl;
        cout<<"(3) Normal Stress [in MPa] :"<<sigma<<endl;
        cout<<endl;
} }
```

Screenshots of written code:

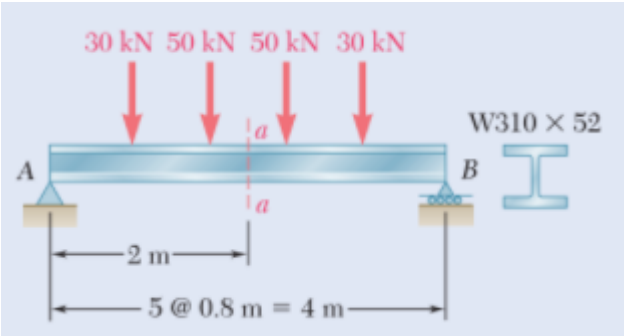
```cpp
#include <iostream>
using namespace std;

int main(){

    int n; //number of point loads
    float a; //distance between support A and left end of the beam
    float b; //distance between support B and right end of the beam
    float l; //span of the beam
    float s; //section modulus of the beam

    cout<<"INPUT :"<<endl;
    cout<<endl;

    cout<<"Enter the number of point loads :";
    cin>>n;
    cout<<endl;

    cout<<"Distance between support A and left end of the beam [in mm] :";
    cin>>a;
    cout<<endl;

    cout<<"Distance between support B and right end of the beam [in mm] :";
    cin>>b;
    cout<<endl;

    cout<<"Span of the beam [in mm] :";
    cin>>l;
    cout<<endl;

    cout<<"Section modulus of the beam [in mm^3] :";
    cin>>s;
    cout<<endl;


    float loads[n]; // array to store the value of each load
    float dist_of_loads[n]; // array to store the distance of each load from left end

    float sumP=0; //summation of all loads
    float reactionB=0; //reaction forceat end A
    float reactionA=0; //reaction force at end B

    for(int i=1;i<=n;i++){

        cout<<"Enter the point load p"<<i<<" [in N] :";
        cin>>loads[i];

        cout<<"Enter the distance x"<<i<<" of load p"<<i<<" from left end [in mm] :";
        cin>>dist_of_loads[i];

        cout<<endl;

        sumP=sumP+ loads[i];
        reactionB=reactionB + (loads[i]*(dist_of_loads[i]-a))/l;
```

```
55
56      }
57
58      reactionA=sumP-reactionB;
59
60      int m; // number of cross sections at which stress is to be found
61
62      cout<<"Enter the number of Cross Sections at which stress is to be found :";
63      cin>>m;
64      cout<<endl;
65
66      float dist[m]; //array of distances of cross sections at which stress is to be calculated
67
68      for(int j=1;j<=m;j++){
69
70          cout<<"Enter the distance of Cross section "<<j<<" [in mm] :";
71          cin>>dist[j];
72          cout<<endl;
73      }
74
75      cout<<"OUTPUT :"<<endl;
76      cout<<endl;
77      cout<<"Reaction force at A [in kN] :"<<reactionA/1000<<endl;
78      cout<<"Reaction force at b [in kN] :"<<reactionB/1000<<endl;
79      cout<<endl;
80
81      for(int k=1;k<=m;k++){
82
83          float c=0,d=0;
84          int stepA,stepB,stepI;
85
86          if(dist[k]>=a){
87              stepA=1;
88          }
89          else
90              stepA=0;
91
92
93          if(dist[k]>=a+l){
94              stepB=1;
95          }
96          else
97              stepB=0;
98
99
100         float V; //shear stress
101         float M; // bending moment
102         float sigma; // normal stress
103
104         for(int i=1;i<=n;i++){
105
106             if(dist[k]>=dist_of_loads[i]){
107
108                 stepI=1;
```

```
            }
            else
                stepI=0;


            c=c+loads[i]*stepI;
            d=d+loads[i]*(dist[k]-dist_of_loads[i])*stepI;

            V=reactionA*stepA + reactionB*stepB -c;
            M=reactionA*(dist[k]-a)*stepA +reactionB*(dist[k]-a-l)*stepB - d;
            sigma=M/s;

            if(dist[k]>l){
                V=M=sigma=0;
            }
        }

        cout<<"At x="<<dist[k]/1000<<" m :"<<endl;
        cout<<"(1) Shear Stress [in kN] :"<<V/1000<<endl;
        cout<<"(2) Bending Moment [in kN-m] :"<<M/1000000<<endl;
        cout<<"(3) Normal Stress [in MPa] :"<<sigma<<endl;

        cout<<endl;
    }

}
```

SAMPLE INPUT AND OUTPUT FOR THE GIVEN CODE:

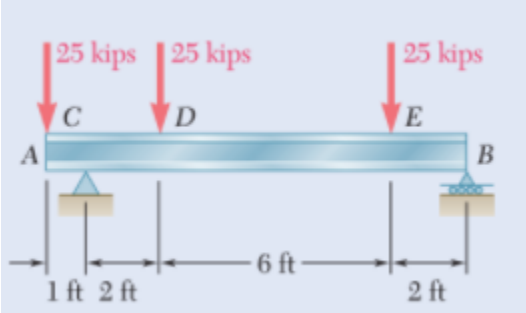
1)



INPUT AND OUTPUT:

```
PS D:\cpp practice> & '.\me project.exe'
INPUT :

Enter the number of point loads :4

Distance between support A and left end of the beam [in mm] :0

Distance between support B and right end of the beam [in mm] :0

Span of the beam [in mm] :4000

Section modulus of the beam [in mm^3] :809000

Enter the point load p1 [in N] :30000
Enter the distance x1 of load p1 from left end [in mm] :800

Enter the point load p2 [in N] :50000
Enter the distance x2 of load p2 from left end [in mm] :1600

Enter the point load p3 [in N] :50000
Enter the distance x3 of load p3 from left end [in mm] :2400

Enter the point load p4 [in N] :30000
Enter the distance x4 of load p4 from left end [in mm] :3200

Enter the number of Cross Sections at which stress is to be found :1

Enter the distance of Cross section 1 [in mm] :2000

OUTPUT :

Reaction force at A [in kN] :80
Reaction force at b [in kN] :80

At x=2 m :
(1) Shear Stress [in kN] :0
(2) Bending Moment [in kN-m] :104
(3) Normal Stress [in MPa] :128.554
```

2)



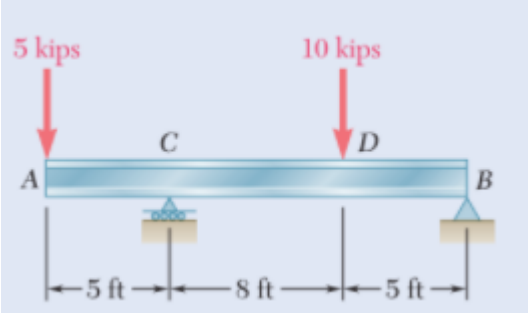
INPUT:

```
PS D:\cpp practice> & '.\me project.exe'
INPUT :

Enter the number of point loads :3

Distance between support A and left end of the beam [in mm] :304.8

Distance between support B and right end of the beam [in mm] :0

Span of the beam [in mm] :3048

Section modulus of the beam [in mm^3] :625000

Enter the point load p1 [in N] :111205.54
Enter the distance x1 of load p1 from left end [in mm] :0

Enter the point load p2 [in N] :111205.54
Enter the distance x2 of load p2 from left end [in mm] :914.4

Enter the point load p3 [in N] :111205.54
Enter the distance x3 of load p3 from left end [in mm] :2743.2

Enter the number of Cross Sections at which stress is to be found :4

Enter the distance of Cross section 1 [in mm] :0

Enter the distance of Cross section 2 [in mm] :1524

Enter the distance of Cross section 3 [in mm] :2743.2

Enter the distance of Cross section 4 [in mm] :3352.8
```

OUTPUT:

```
OUTPUT :

Reaction force at A [in kN] :233.532
Reaction force at b [in kN] :100.085

At x=0 m :
(1) Shear Stress [in kN] :-111.206
(2) Bending Moment [in kN-m] :-0
(3) Normal Stress [in MPa] :-0

At x=1.524 m :
(1) Shear Stress [in kN] :11.1206
(2) Bending Moment [in kN-m] :47.4536
(3) Normal Stress [in MPa] :75.9258

At x=2.7432 m :
(1) Shear Stress [in kN] :-100.085
(2) Bending Moment [in kN-m] :61.0118
(3) Normal Stress [in MPa] :97.6189

At x=3.3528 m :
(1) Shear Stress [in kN] :0
(2) Bending Moment [in kN-m] :0
(3) Normal Stress [in MPa] :0
```

3)



INPUT:

```
PS D:\cpp practice> & '.\me project.exe'
INPUT :

Enter the number of point loads :2

Distance between support A and left end of the beam [in mm] :1524

Distance between support B and right end of the beam [in mm] :0

Span of the beam [in mm] :3962.4

Section modulus of the beam [in mm^3] :1030000

Enter the point load p1 [in N] :22241.11
Enter the distance x1 of load p1 from left end [in mm] :0

Enter the point load p2 [in N] :44482.22
Enter the distance x2 of load p2 from left end [in mm] :3962.4

Enter the number of Cross Sections at which stress is to be found :4

Enter the distance of Cross section 1 [in mm] :0

Enter the distance of Cross section 2 [in mm] :1524

Enter the distance of Cross section 3 [in mm] :3962.4

Enter the distance of Cross section 4 [in mm] :5486.4
```

OUTPUT:

```
OUTPUT :

Reaction force at A [in kN] :47.9039
Reaction force at b [in kN] :18.8194

At x=0 m :
(1) Shear Stress [in kN] :-22.2411
(2) Bending Moment [in kN-m] :-0
(3) Normal Stress [in MPa] :-0

At x=1.524 m :
(1) Shear Stress [in kN] :25.6628
(2) Bending Moment [in kN-m] :-33.8955
(3) Normal Stress [in MPa] :-32.9082

At x=3.9624 m :
(1) Shear Stress [in kN] :-18.8194
(2) Bending Moment [in kN-m] :28.6808
(3) Normal Stress [in MPa] :27.8454

At x=5.4864 m :
(1) Shear Stress [in kN] :0
(2) Bending Moment [in kN-m] :0
(3) Normal Stress [in MPa] :0
```

GITHUB LINK OF FINAL PROJECT:

https://github.com/riya7701/ME212-project

THANK YOU!