

Mathematics Lab Assessment No.3

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Question 1) find displacement u_1, u_2, u_3, u_4 ,Solve by Gauss Elimination method

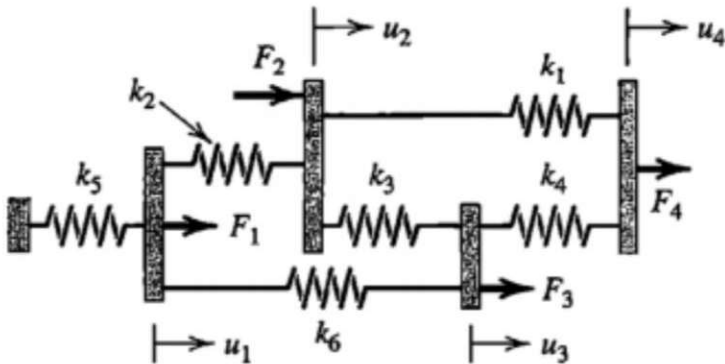


Fig 1: Springs and blocks arrangement

Springs and blocks arrangement is shown in Fig 1. The displacement of springs allowed in horizontal direction only and the blocks are considered as rigid and connected linear springs with stiffness. **Write the system of equilibrium of equations for the applied forces $F_1=2F_2=20$ kN, $F_3=F_4=30$ kN. Evaluate the displacement fields for the applied loads**

$$\begin{aligned} k_1 &= 100 \text{ N/m} & k_2 &= 200 \text{ N/m} & k_3 &= 300 \text{ N/m} \\ k_4 &= 500 \text{ N/m} & k_5 &= 400 \text{ N/m} & k_6 &= 150 \text{ N/m} \end{aligned}$$

2) Solve the following system by LU Decomposition method

$$\begin{aligned} \text{i)} \quad & x_1 - 3x_2 + x_3 = -5 \\ \text{ii)} \quad & 2x_1 - 2x_2 + 4x_3 = 0 \\ \text{iii)} \quad & 3x_1 + 2x_2 + 5x_3 = 7 \end{aligned}$$

Solution i) Identify the parameters and mathematical concept

1)
System type: Linear spring-mass system
Unknowns: Displacements $u_1, u_2, u_3, u_4, u_5, u_6$
Loads: F_1, F_2, F_3, F_4
2)
Unknowns: x_1, x_2, x_3

ii) Solve analytically
1)

Gauss Elimination.

$$\begin{bmatrix} 750 & -200 & -150 & 0 \\ -200 & 600 & -300 & -100 \\ -150 & -300 & 950 & -500 \\ 0 & -100 & -500 & 600 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} 20 \\ 10 \\ 30 \\ 30 \end{bmatrix}$$

Divide by .50.

$$\begin{bmatrix} 15 & -4 & 3 & 0 \\ -4 & 12 & -6 & -2 \\ -3 & -6 & 19 & -10 \\ 0 & -2 & -10 & 12 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} 20 \\ 10 \\ 30 \\ 30 \end{bmatrix}$$

$$R_2 = 15R_2 + 4R_1$$

$$R_3 = 5R_3 + R_1$$

$$\begin{bmatrix} 15 & -4 & 3 & 0 \\ 0 & 64 & -78 & -30 \\ 0 & -34 & 98 & -50 \\ 0 & -2 & -10 & 12 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} 20 \\ 10 \\ 30 \\ 30 \end{bmatrix}$$

By solving the above matrix we get,

$$u_1 = 0.225$$

$$u_2 = 0.4$$

$$u_3 = 0.45$$

$$u_4 = 0.49$$

iii) GeoGebra Screenshot / Program Execution

CODE

1)

```
import numpy as np
#B=np.array([[2,1,1,10],
#           [3,2,3,18],
#           [1,4,9,16]],
#           dtype=float)

A=np.array([[ 750, -200, -150,  0,20],
            [-200,  600, -300, -100,10],
            [-150, -300,  950, -500,30],
            [  0, -100, -500,  600,30]],dtype=float)

n=len(A)

for i in range(n):
    pivot=A[i][i]
    A[i]=A[i]/pivot
    for j in range (i+1,n):
        A[j]=A[j]-A[j][i]*A[i]

x=np.zeros(n)

for i in range (n-1,-1,-1):
    x[i]=A[i][n]-np.sum(A[i][i+1:n]*x[i+1:n])

print("SOLUTIONS:")
print("x=",x[0])
print("y=",x[1])
print("z=",x[2])
print("a=",x[3])
```

2)

```
import numpy as np

def lu_decompose(A):
    A = A.astype(float)
    n = A.shape[0]
    L = np.eye(n)
    U = A.copy()

    for i in range(n):
        for j in range(i+1, n):
            factor = U[j, i] / U[i, i]
            L[j, i] = factor
            U[j] = U[j] - factor * U[i]
    return L, U

def solve_LU(A, b):
    L, U = lu_decompose(A)
    n = A.shape[0]

    y = np.linalg.solve(L, b)
    x = np.linalg.solve(U, y)

    return x

A = np.array([[1, -3, 1],
              [0, 4, 2],
              [0, 0, -6]])

b = np.array([-5, 10, -18])

x = solve_LU(A, b)
print("Solution x:", x)
```

OUTPUT

1)

```
a= 0.2250000000000002  
b= 0.40215736040609174  
c= 0.4554568527918786  
d= 0.4965736040609141
```

So, The displacement fields calculated via the Gauss Elimination program are:

- $u_1 = 0.2250$
- $u_2 = 0.4021$
- $u_3 = 0.4554$
- $u_4 = 0.4965$

2)

```
L:  
[[1. 0. 0.]  
 [0. 1. 0.]  
 [0. 0. 1.]]  
U:  
[[ 1. -3.  1.]  
 [ 0.  4.  2.]  
 [ 0.  0. -6.]]  
Solution x:  
[-5.  1.  3.]
```

$x_1 = 2, x_2 = 1, x_3 = 2$