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Lab #7 Solving Systems of Linear Equations

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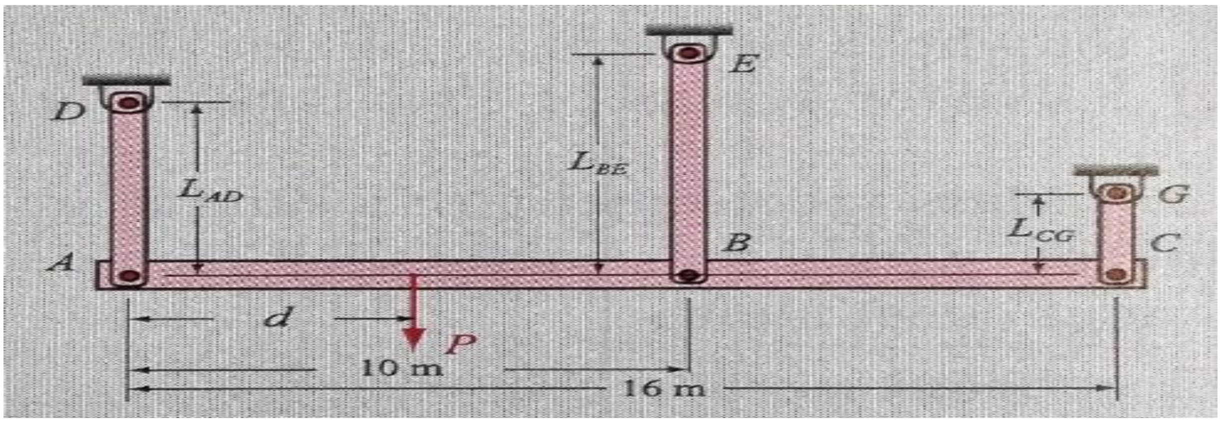
Problem: *Bar Material Selection2*
As shown in the figure to the right, a rigid bar ABC is suspended by three vertical bars that have square cross-sections. As part of your summer research position you have been asked to answer the following using your MATLAB skills:



1) Determine which of the following materials can be used for all of the vertical bars in order to ensure that for P=90 kN and any value of d (i.e., $0 \leq d \leq 16$ m) none of the bars elongate by more than 0.1% of their original length. If more than one material qualifies, you need to pick the lightest one.

- Aluminum Alloy 1100 (E=75GPa, density=2740kg/m3)
- Nickel 200 (E=209GPa, density=8890kg/m3)
- Steel Alloy 4340 (E=197GPa, density=7850kg/m3)

To solve the first question, I understand that a P force of 90 kN will be applied, and that cross-sectional area of bar must be 0.0004 m^2. Therefore, I set these two values to CSA and ForceP:

```
CSA = 0.0004;
ForceP = 90000;
```

Next, I used the different Young's Modulus values to create a row matrix E. I also created a matrix D for each distance value from 1 to 16. I also created a matrix L for the length of the bars AD, BE and CG:

```
E = [75000000000, 209000000000, 197000000000];
D = [1:1:16];
L = [4, 5, 2];
```

Using the following set of equations:
$F_{AD}+F_{BE}+F_{CG}=P$
$10F_{BE}+16F_{CG}=dP$

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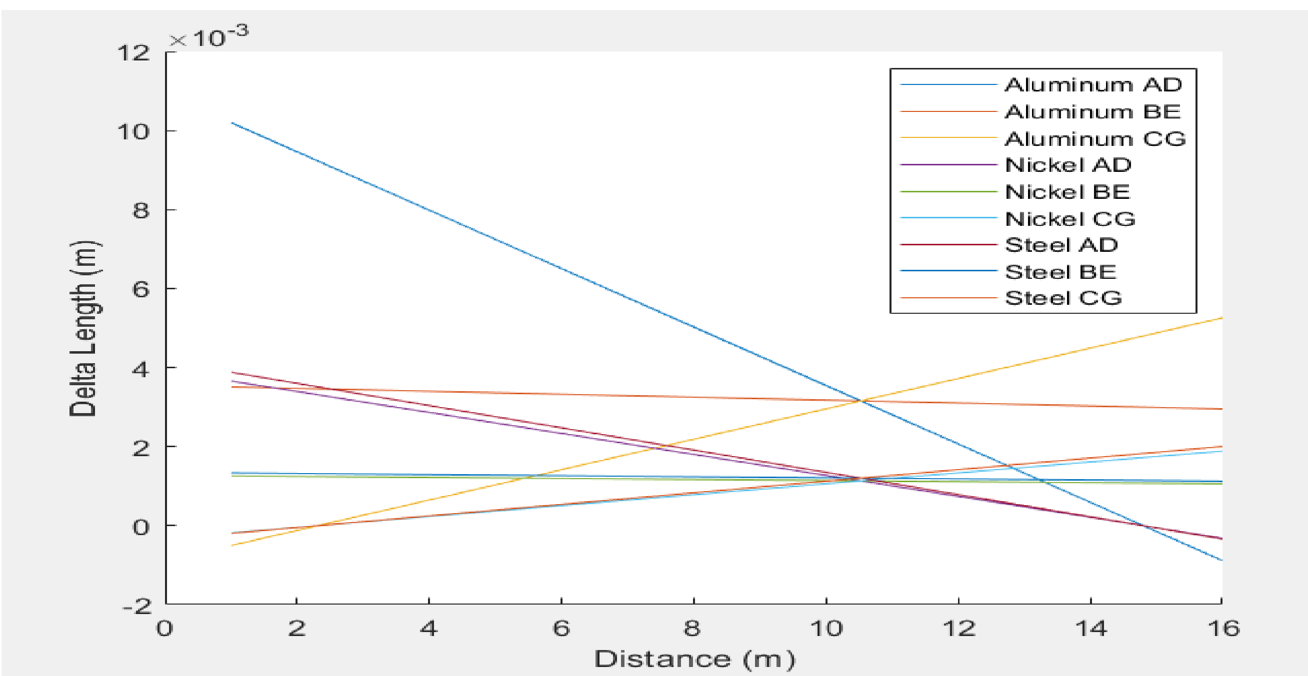
$6\Delta L_{AD} - 16\Delta L_{BE} + 10\Delta L_{CG} = 0$

$\Delta L = FL/EA$

I used a for loop to do the calculations:

```
for i = 1:1:3
%   Reset variables
    F = zeros(3,1);
    e = E(i);
    for d = 1:1:16
%       Declare matrix by subbing delta L for the force
        C = [1 1 1 ForceP; 0 10 16 d*ForceP; 24/(e*CSA) -
80/(e*CSA) +20/(e*CSA) 0];
%       Solve the matrix by finding rref and adding it to f per
d
        RC = rref(C);
        F = [F RC(:,4)];
    end
%   Loop for every member in the structure
    for m = 1:1:3
%       Create a matrix for delta L using the F values to solve
        l = F(m,2:17)*(L(m)/(e*CSA));
%       Plot l
        hold on;
        plot(D, l);
    end
end
```



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From this plot, we determine that only Nickel is the only material for which the elongation is less than 0.1% of its original length. Steel would be a cheaper option, due to the fact that it is lighter, however, its elongation is higher than 0.1% when d = 0 or 16. Aluminum's elongations is also way higher than 0.1% than its original length, therefore it can't be considered.

In conclusion, Nickel is the only material that can be used for all of the vertical bars in order to ensure that for P=90 kN and any value of d (i.e., $0 \leq d \leq 16$ m) none of the bars elongate by more than 0.1% of their original length.

2) For your choice of material, identify where, if possible, to properly locate the weight on the horizontal bar such that the bar remains horizontal.

The bar will remain horizontal when the weight is located at 10.5 m to the right of Joint A. As it can be seen in the graph, at a distance of 10.5, all three lines, Nickel AD, Nickel BE, and Nickel CG have the same delta Length. This means that this is the point where the weight should be placed to ensure that that the members AD, BE, and CG elongate the same length, and allow the bar to remain horizontal and balance the weight.

*Note I combined the three individual graphs (Aluminum, Nickel and Steel) for efficiency and easiness to read.