MECHANICS PROJECT

A Project Report Submitted to Amrita School of Engineering (Chennai) in partial fulfilment of the Requirements for the Degree of Bachelor of Technology in Computer Science and Engineering (Artificial Intelligence)

COMPUTATIONAL ENGINEERING MECHANICS - 1 (19PHY104)

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in partial fulfillment for the 1st semester

of

BACHELOR OF TECHNOLOGY

IN

ARTIFICIAL INTELLIGENCE

AMRITA SCHOOL OF ENGINEERING, CHENNAI

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CHENNAI

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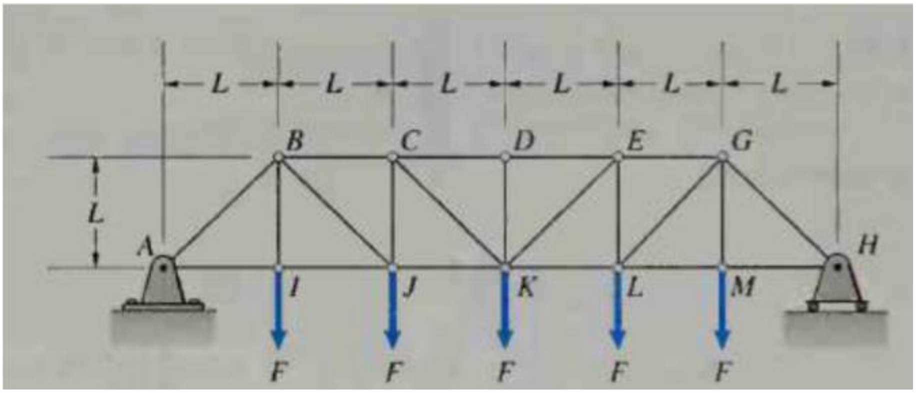
Question :

Determine the member forces of the Pratt bridge truss. The force F varies from 100 kN to 500 kN and L varies from 4 m to 8 m.



Solution :

According to F.B.D of the truss ,

We are assuming that all the members are in tension, if suppose the value is negative then it means that the member is in compression.

$\sum F_y = 0$

$$A_y + H_y = 5F$$

$$F = \frac{A_y + H_y}{5} \quad \rightarrow \quad [1]$$

$\sum M_A = 0$

$$= LF + 2LF + 3LF + 4LF + 5LF - 6H_yL = 0$$

$$15F = 6H_y \quad \rightarrow \quad [2]$$

From the equation [2] ,we can say that the forces in the members are independent of the length, because H_y is only dependent on F.

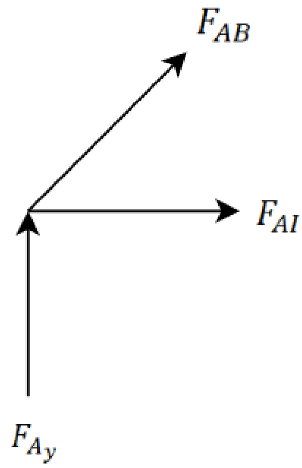
As the length and the height are same ,θ = 45° (by pythagoras theorem)

[2] in [1]

$$F = \frac{\frac{15F}{6} + A_y}{5}$$

$$A_y = \frac{15F}{6} \qquad \rightarrow \quad [3]$$

<u>Now, at joint A :</u>



$\sum F_y = 0$

$$\sum F_y = F_{AB} sin45^{\circ} + F_{A_y} = 0$$

$$F_{AB} = \frac{-15\sqrt{2}}{6} F$$

$\Rightarrow$ In compression (-ve)

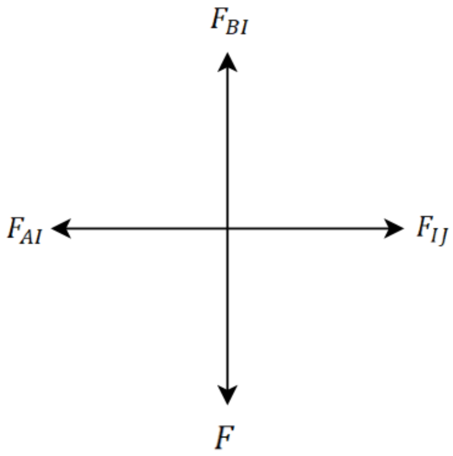
$\sum F_x = 0$

$$\sum F_x = F_{AB} cos45^{\circ} + F_{AI} = 0$$

$$F_{AI} = -F_{AB} cos45^{\circ}$$

$$F_{AI} = \frac{15}{6} F$$

Now, at joint I :



$\sum F_y = 0$

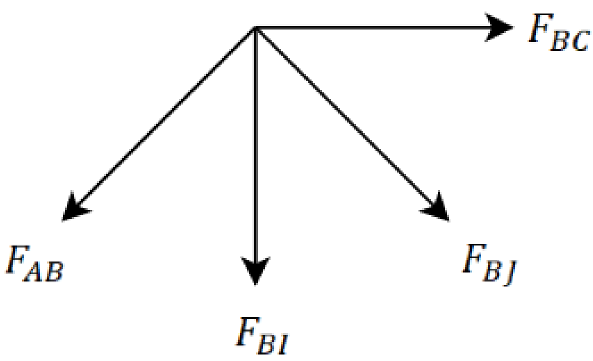
$$F - F_{BI} = 0$$

$$F_{BI} = F$$

$\sum F_x = 0$

$$F_{IJ} = F_{AI} = \frac{15}{6}F$$

Now, at joint B :



$\sum F_y = 0$

$$-F_{BI} - F_{AB} sin45^{\circ} - F_{BJ} sin45^{\circ} = 0$$

$$-F - \left(\frac{-15\sqrt{2}}{6}F\right)\left(\frac{1}{\sqrt{2}}\right) - \frac{F_{BJ}}{\sqrt{2}} = 0$$

$$F_{BJ} = (1.5)(\sqrt{2})F$$

$\sum F_x = 0$

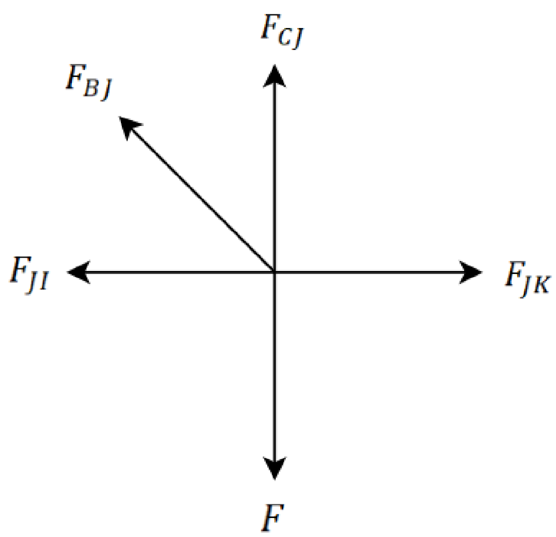
$$-F_{AB}cos45^{\circ} + F_{BJ}cos45^{\circ} + F_{BC} = 0$$

$$= -\left(\frac{-15\sqrt{2}}{6}F\right)\left(\frac{1}{\sqrt{2}}\right) + \frac{(1.5F)(\sqrt{2})}{\sqrt{2}} + F_{BC}$$

$$F_{BC} = -4\ F$$

$\Rightarrow$ In compression (-ve)

<u>Now, at joint J :</u>



$\sum F_y = 0$

$$F_{CJ} + F_{BJ}sin45^{\circ} - F = 0$$

$$F_{CJ} = F - \frac{(1.5F)(\sqrt{2})}{\sqrt{2}}$$

$$F_{CJ} = -0.5F$$

$\Rightarrow$ In compression (-ve)

$\sum F_x = 0$

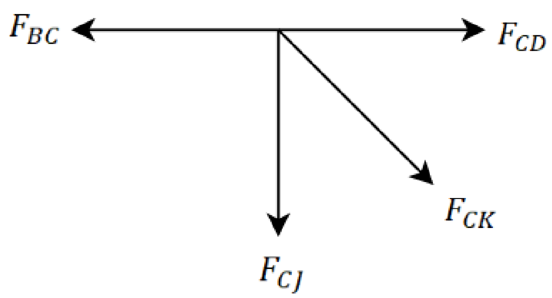
$$F_{JK} - F_{BJ} cos45° - F_{JI} = 0$$

$$F_{JK} = F_{BJ} cos45° + F_{JI}$$

$$= \frac{(1.5F)(\sqrt{2})}{\sqrt{2}} + \frac{15F}{6}$$

$$F_{JK} = 4\ F$$

<u>Now, at joint C :</u>



$\sum F_y = 0$

$$F_{CJ} + F_{CK}\ sin45° = 0$$

$$F_{CK} = (0.5)(\sqrt{2})\ F$$

$\sum F_x = 0$

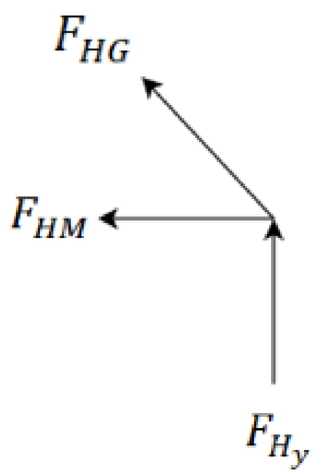
$$F_{CK} cos45° + F_{CD} - F_{BC} = 0$$

$$-4F = \frac{F}{2} + F_{CD}$$

$$F_{CD} = -4.5\ F$$

$\Rightarrow$ In compression (-ve)

<u>Now, at joint H :</u>



$\sum F_y = 0$

$$\sum F_y = F_{HG} sin45^{\circ} + F_{H_y} = 0$$

$$F_{HG} = \frac{-15\sqrt{2}}{6} F$$

$\Rightarrow$ In compression (-ve)

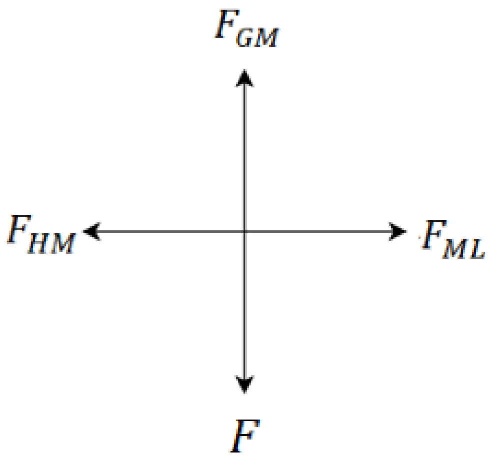
$\sum F_x = 0$

$$\sum F_x = F_{HG} cos45^{\circ} + F_{HM} = 0$$

$$F_{HM} = -F_{HG} cos45^{\circ}$$

$$F_{HM} = \frac{15}{6} F$$

<u>Now, at joint M :</u>



$\sum F_y = 0$

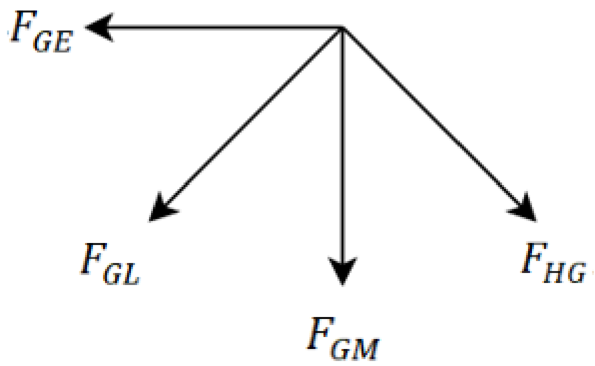
$$F - F_{GM} = 0$$

$$F_{GM} = F$$

$\sum F_x = 0$

$$F_{ML} = F_{HM} = \frac{15}{6} F$$

Now, at joint G :



$\sum F_y = 0$

$$-F_{GM} - F_{HG} sin45\,^{\circ} - F_{GL} sin45\,^{\circ} = 0$$

$$-F - \left(\frac{-15\sqrt{2}}{6}F\right)\left(\frac{1}{\sqrt{2}}\right) - \frac{F_{GL}}{\sqrt{2}} = 0$$

$$F_{GL} = (1.5)(\sqrt{2})F$$

$\sum F_x = 0$

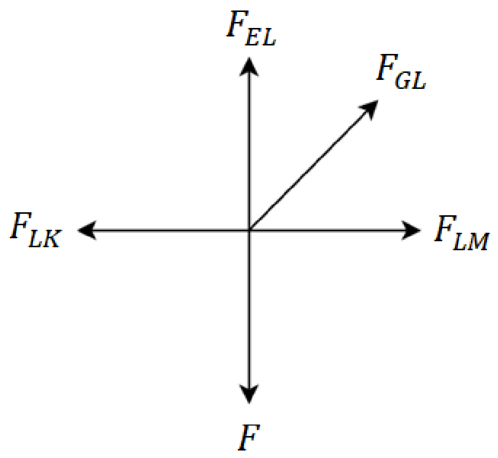
$$-F_{HG} cos45\,^{\circ} + F_{GL} cos45\,^{\circ} + F_{GE} = 0$$

$$= -\left(\frac{-15\sqrt{2}}{6}F\right)\left(\frac{1}{\sqrt{2}}\right) + \frac{(1.5F)(\sqrt{2})}{\sqrt{2}} + F_{GE}$$

$$F_{GE} = -4\,F$$

$\Rightarrow$ In compression (-ve)

Now, at joint L :



$\sum F_y = 0$

$$F_{EL} + F_{GL} sin45\,^{\circ} - F = 0$$

$$F_{EL} = F - \frac{(1.5F)(\sqrt{2})}{\sqrt{2}}$$

$$F_{EL} = -0.5F$$

$\Rightarrow$ In compression (-ve)

$\sum F_x = 0$

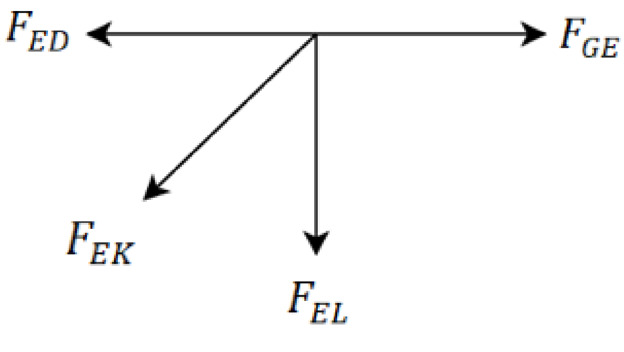
$$F_{LK} - F_{GL} cos45\,^{\circ} - F_{LM} = 0$$

$$F_{LK} = F_{GL} cos45\,^{\circ} + F_{LM}$$

$$= \frac{(1.5F)(\sqrt{2})}{\sqrt{2}} + \frac{15F}{6}$$

$$F_{LK} = 4\ F$$

<u>Now, at joint E :</u>



$\sum F_y = 0$

$$F_{EL} + F_{EK}\ sin45\,^{\circ} = 0$$

$$F_{EK} = (0.5)(\sqrt{2})\ F$$

$\sum F_x = 0$

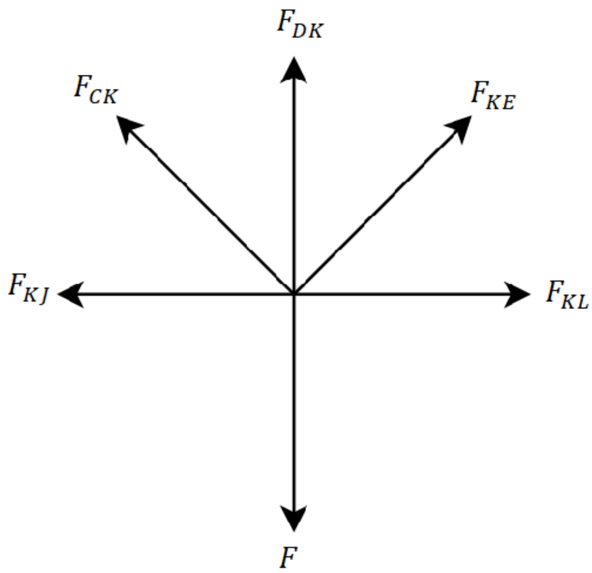
$$F_{EK} cos45^{\circ} + F_{ED} - F_{GE} = 0$$

$$-4F = \frac{F}{2} + F_{ED}$$

$$F_{ED} = -4.5\ F$$

$\Rightarrow$ In compression (-ve)

<u>Now, at joint K :</u>



$\sum F_y = 0$

$$F_{DK} + F_{EK}\ sin45^{\circ} + F_{CK}\ sin45^{\circ} - F = 0$$

$$F_{DK} + \frac{F_{KE}}{\sqrt{2}} + \frac{F_{CK}}{\sqrt{2}} = F$$

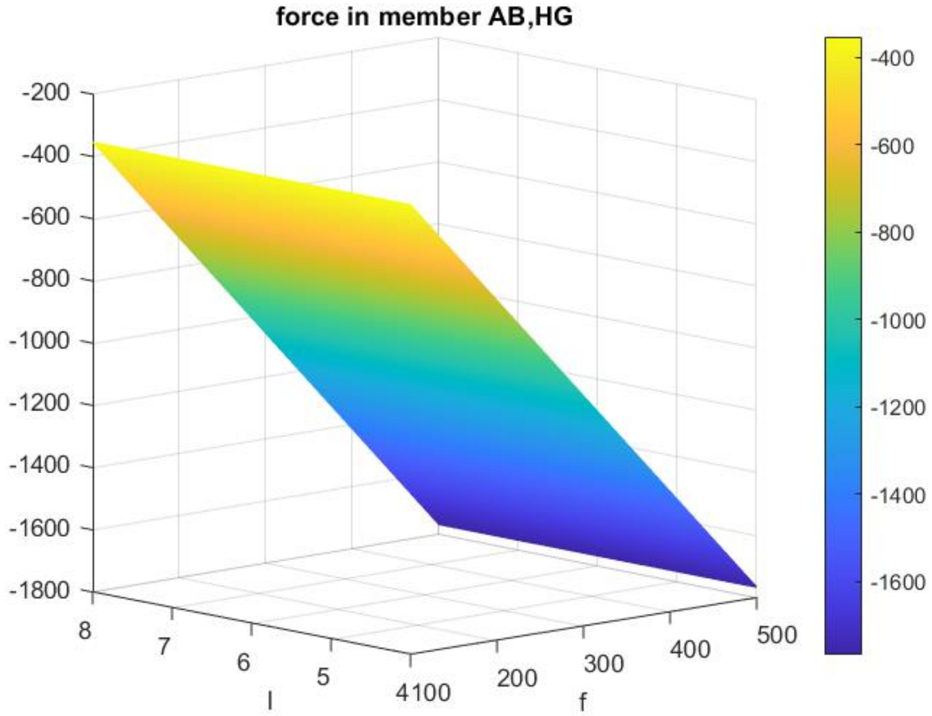
$$F_{EK} = F_{CK} = \frac{F}{\sqrt{2}}$$

$$F_{DK} + \frac{F}{\sqrt{2}} + \frac{F}{\sqrt{2}} = F$$

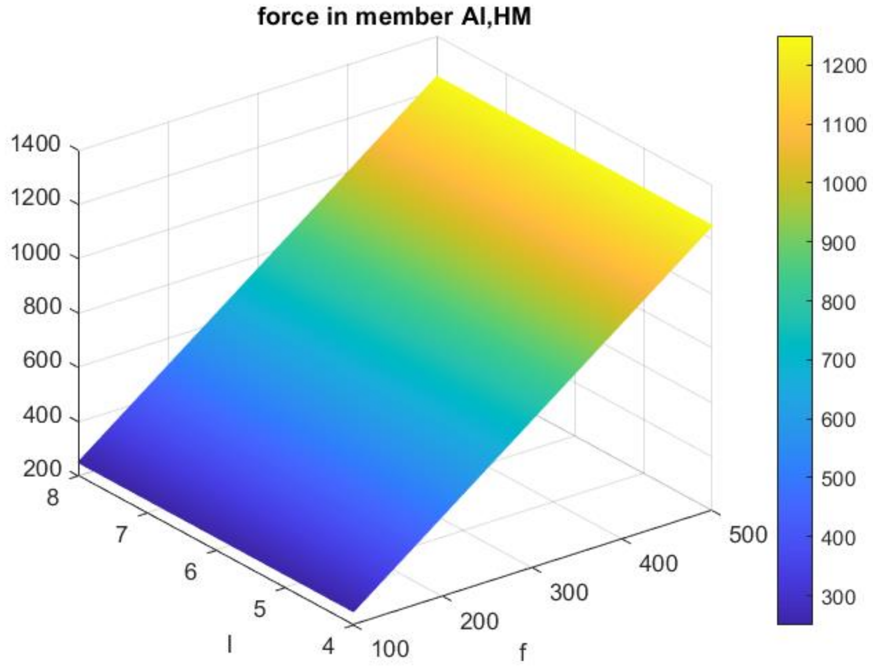
$$F_{DK} = 0$$

MATLAB CODE :

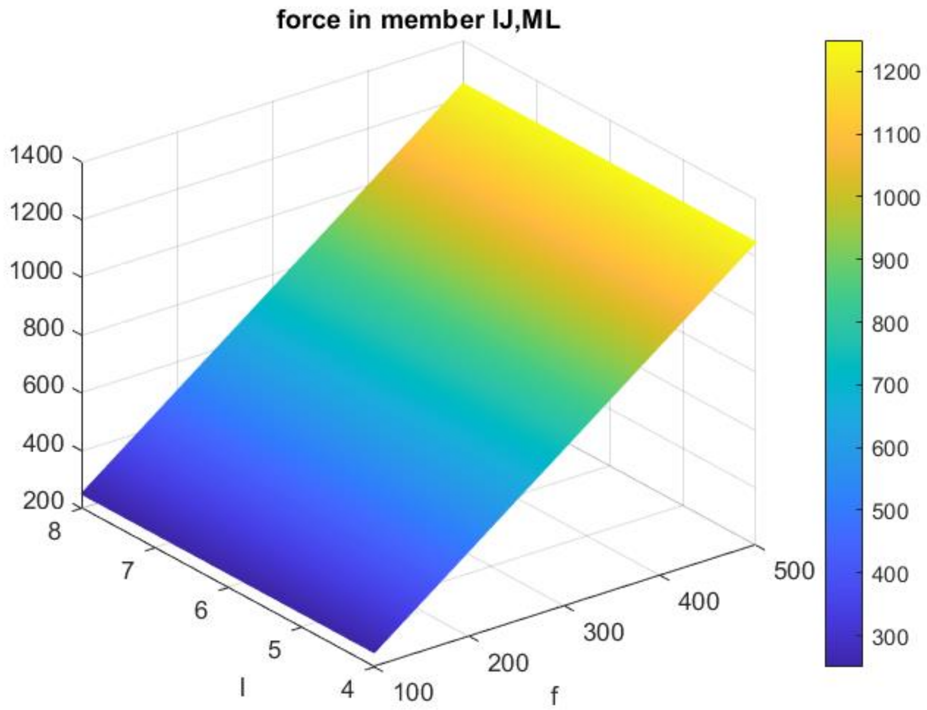
```
[f,l]=meshgrid(100:1:500,4:0.01:8);
Fab=((-15*sqrt(2))/6)*f;
Fai=(15/6)*f;
Fij=(15/6)*f;
Fib=f;
Fbj=(1.5)*sqrt(2)*f;
Fbc=-4*f;
Fcj=-0.5*f;
Fjk=4*f;
Fck=f/sqrt(2);

mesh(f,l,Fab);
title('force in member AB,HG')
xlabel('f')
ylabel('l')
colorbar
```




```
mesh(f,l,Fai);
title('force in member AI,HM')
xlabel('f')
ylabel('l')
colorbar
```

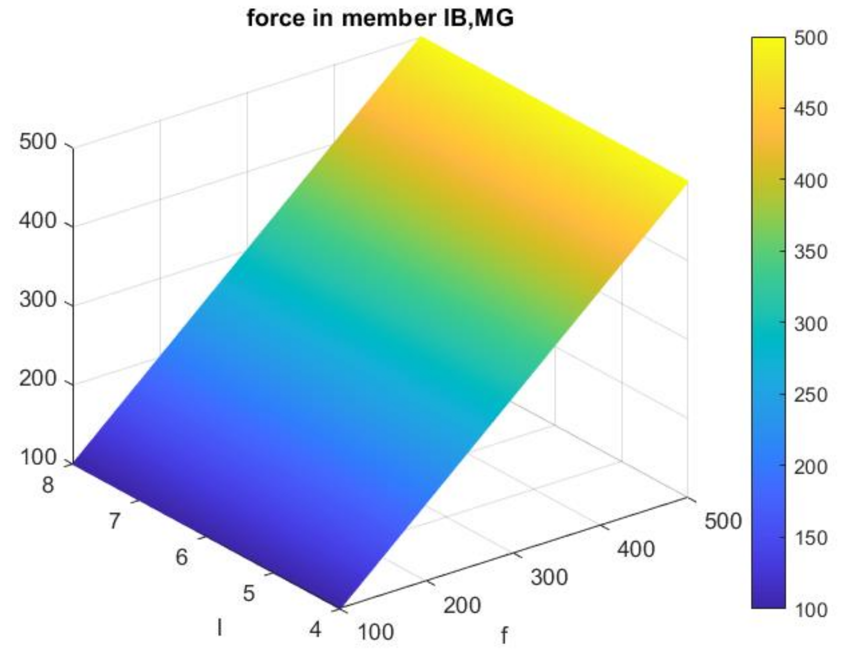



```
mesh(f,l,Fij);
title(['force in member IJ,ML'])
xlabel('f')
ylabel('l')
colorbar
```

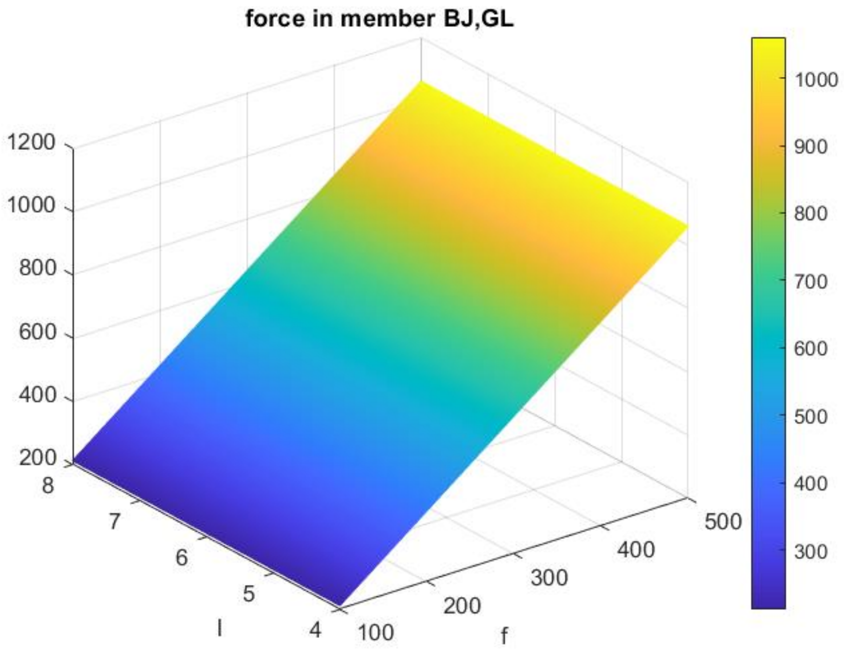



```
mesh(f,l,Fib);
title('force in member IB,MG')
xlabel('f')
ylabel('l')
```

```
colorbar
```

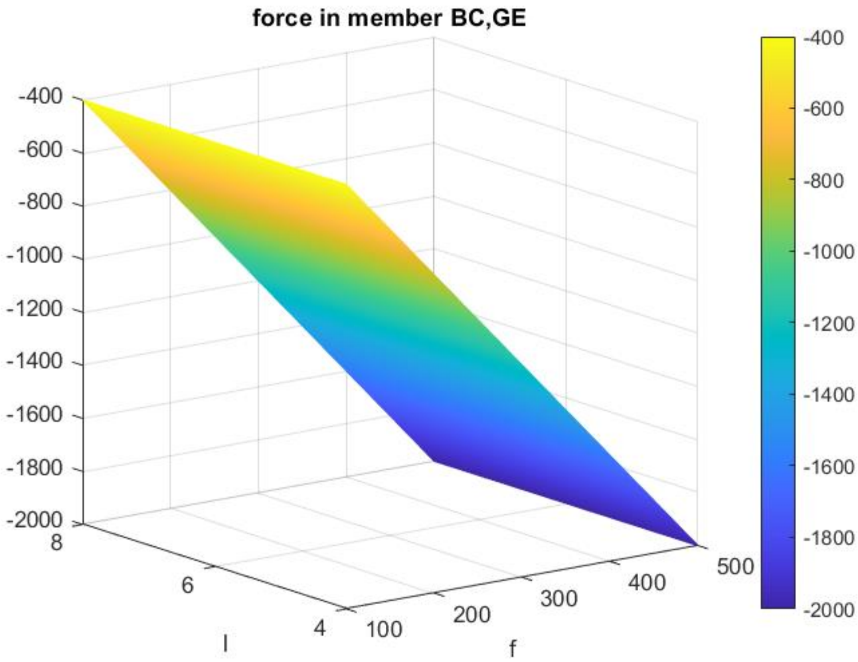



```
mesh(f,l,Fbj);
title('force in member BJ,GL')
xlabel('f')
ylabel('l')
colorbar
```

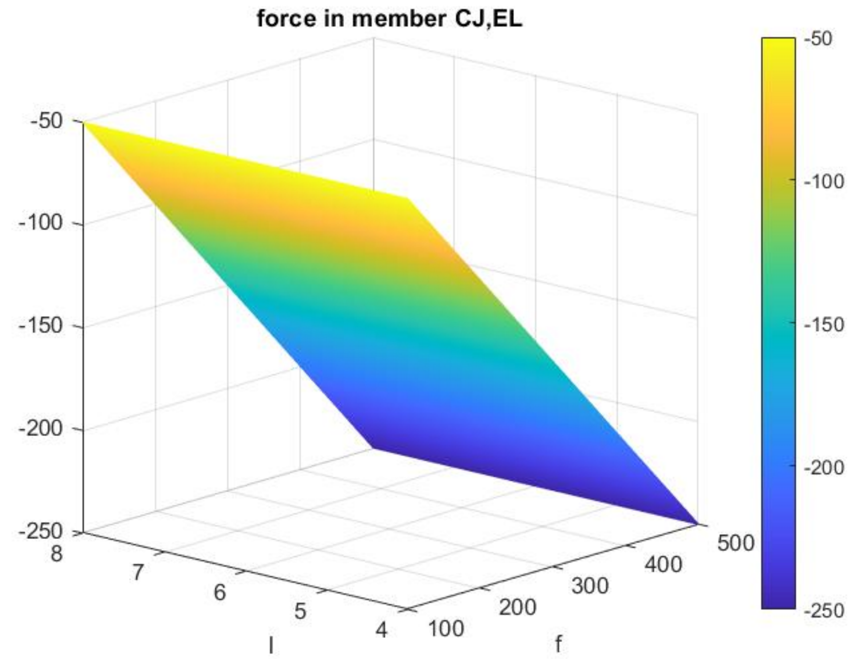



```
mesh(f,l,Fbc);
title('force in member BC,GE')
xlabel('f')
ylabel('l')
```

```
colorbar
```

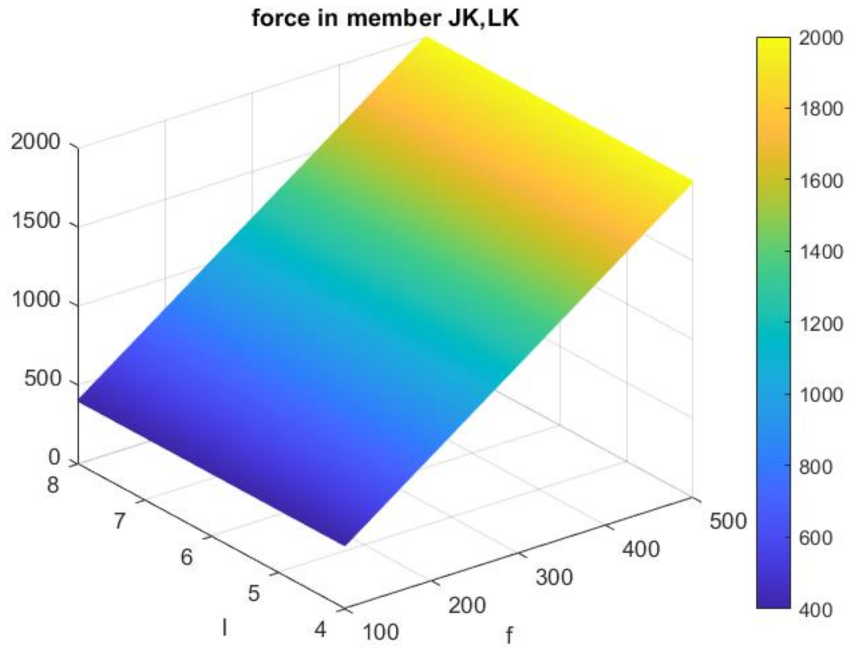



```
mesh(f,l,Fcj);
title('force in member CJ,EL')
xlabel('f')
ylabel('l')
colorbar
```

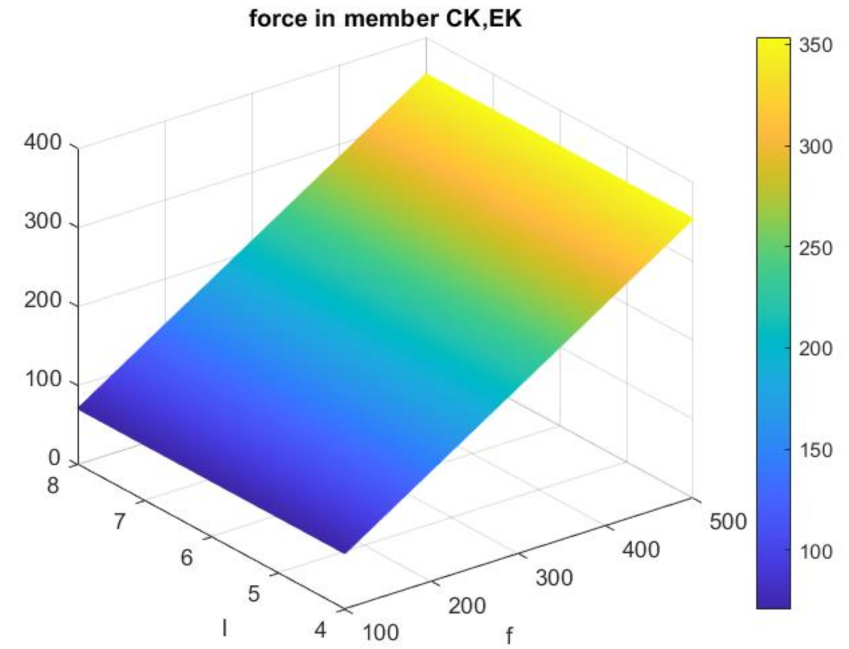



```
mesh(f,l,Fjk);
title('force in member JK,LK')
xlabel('f')
ylabel('l')
```

```
colorbar
```

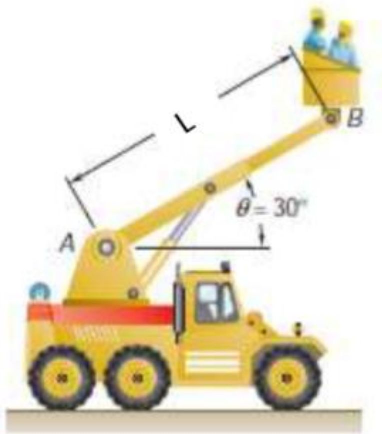



```
mesh(f,l,Fck);
title('force in member CK,EK')
xlabel('f')
ylabel('l')
colorbar
```



Question :

At the instant shown the length of the boom AB is being decreased at the constant rate of v m/s and the boom is being lowered at the constant rate of ω rad/s. Determine the velocity and acceleration of point B. v varies from 0 to 10 m/s, ω varies from 0 to 20 rad/s and L varies from 3 to 10 m.



Solution :

Determining the velocity :

Tangential velocity of the point B,

$v_{Bt} = r_{AB}\omega_{AB}$

Here, r_{AB} is the length of the boom AB and ω_{AB} is the angular velocity of the boom AB.

Substitute L for r_{AB} and **ω** for ω_{AB}.

$$v_{Bt} = (\,L\,m\,)(\,\omega\, rad/sec)$$

$$= L.\,\omega\ m/s$$

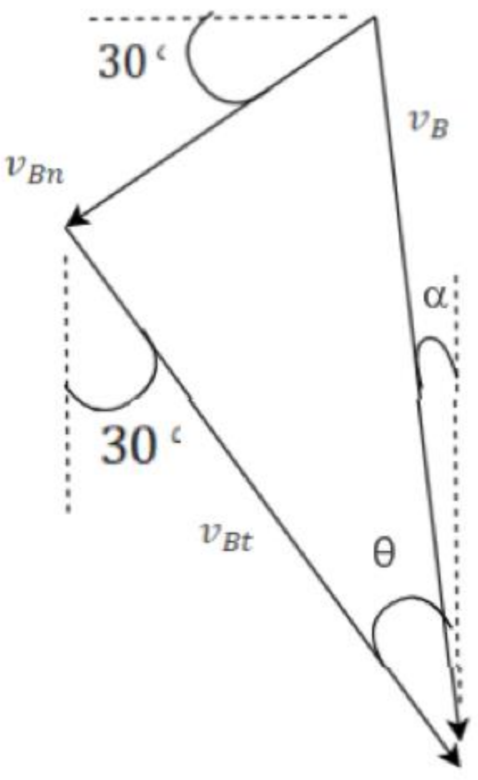
The direction of this velocity is perpendicular to the boom AB and is downwards, as the boom is being lowered.

Normal velocity of the point B,

$$v_{Bn} = v\ m/s$$

The direction of this velocity is in the direction of the boom AB and is downwards, as the boom is being decreased in length.

<u>Draw the velocity triangle</u>



Magnitude of the velocity of the point B,

$v_B^2 = v_{Bt}^2 + v_{Bn}^2$

Substitute $L.\omega\ m/s$ for v_{Bt} and $v\ m/s$ for v_{Bn} .

$$(\boldsymbol{v_{Bt}})^2 + (\boldsymbol{L.\omega})^2 = \boldsymbol{v_B}^2$$

$$v_B = \sqrt{(v_{Bt})^2 + (L.\omega)^2}$$

Calculate the angle α ,

$$\alpha = 30° - \theta$$

$$\theta = \tan^{-1}\left(\frac{v_{Bn}}{v_{Bt}}\right),$$

From the geometry, substitute

$$\alpha = 30° - \tan^{-1}\left(\frac{v_{Bn}}{v_{Bt}}\right)$$

Hence, the velocity of the point B at the instant is $v_B = \sqrt{(v_{Bt})^2 + (L.\omega)^2}$

acting at an angle of $\alpha = 30° - \tan^{-1}\left(\frac{v_{Bn}}{v_{Bt}}\right)$ with the vertical .

Determining the acceleration :

The total acceleration of the point B is the vector sum of its components, namely, normal acceleration, tangential acceleration and coriolis component.

$$\mathbf{a}_B = \mathbf{a}_{Bn} + \mathbf{a}_{Bt} + \mathbf{a}_C$$

As the boom is being lowered at a constant angular velocity, the tangential component of the acceleration is zero. Thus ,

$$\mathbf{a}_{Bt} = 0$$

Calculate the magnitude of the normal component of the acceleration,

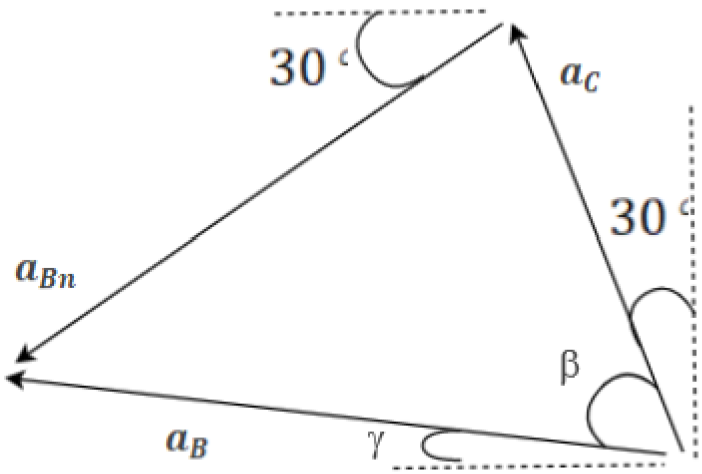
$$a_{Bn} = r_{AB}\omega_B^2$$

Here, r_{AB} is the length of the boom AB and ω_{AB} is the angular velocity of the boom.

Substitute L for r_{AB} and **ω** for ω_{AB}.

$$a_C = (\,L\,m\,)(\,\omega rad/sec)^2$$

Draw the acceleration diagram of the point B



Magnitude of the acceleration of the point B,

$$a_B^2 = a_{Bn}^2 + a_C^2$$

Substitute $L\,\omega^2$ for a_C and $r_{AB}\omega_B{}^2$ for a_{Bn}.

$$(r_{AB}\omega_B{}^2\,)^2 + (L\,\omega^2)^2 = \boldsymbol{a}_B{}^2$$

$$\boldsymbol{a_B} = \sqrt{(r_{AB}\omega_B{}^2\,)^2 + (L\,\omega^2)^2}$$

Calculate the angle γ,

$$\gamma = 60° - \beta$$

From the geometry, substitute

$$\beta = \tan^{-1}\left(\frac{a_{Bn}}{a_C}\right),$$

$$\gamma = 60° - \tan^{-1}\left(\frac{a_{Bn}}{a_C}\right)$$

Therefore, the acceleration of the point B at the given instant is

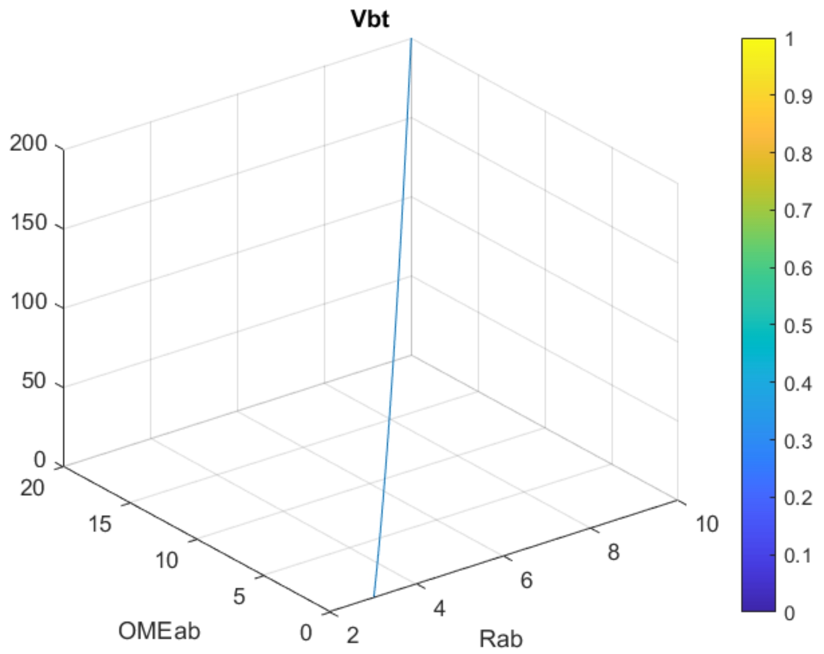
$\boldsymbol{a_B} = \sqrt{(r_{AB}\,\omega_B{}^2\,)^2 + (L\,\omega^2)^2}$ acting at an angle of $\gamma = 60° - \tan^{-1}\left(\frac{a_{Bn}}{a_C}\right)$ with the horizontal.

MATLAB CODE :

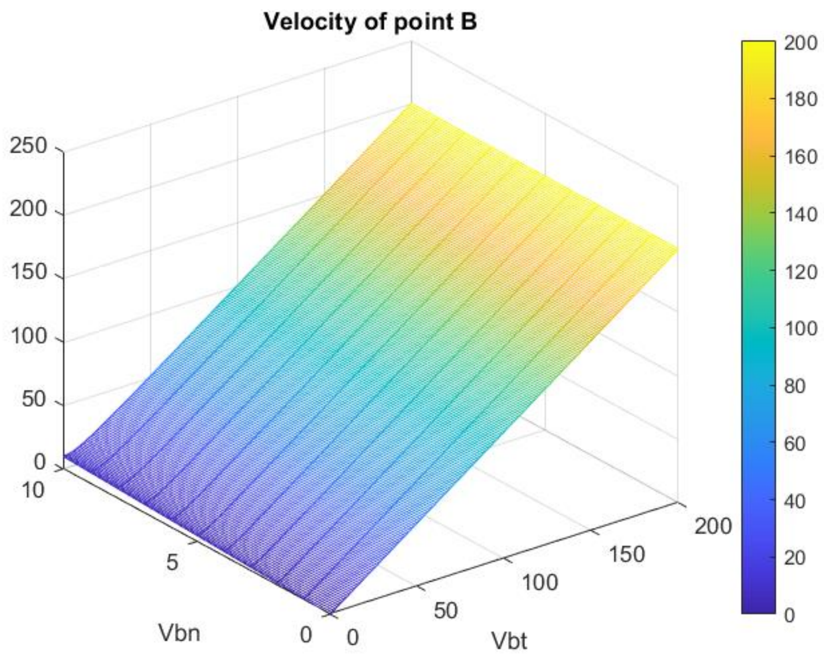
```
"MECH QUESTION 2(PROJECT)"

"velocity"

Rab=linspace(3,10,100);
OMEab=linspace(0,20,100);
Vbt=Rab.*OMEab;
max(Vbt)
```

```
ans = 200
```

```
plot3(Rab,OMEab,Vbt)
grid on
colorbar

title('Vbt')
xlabel('Rab')
ylabel('OMEab')
```



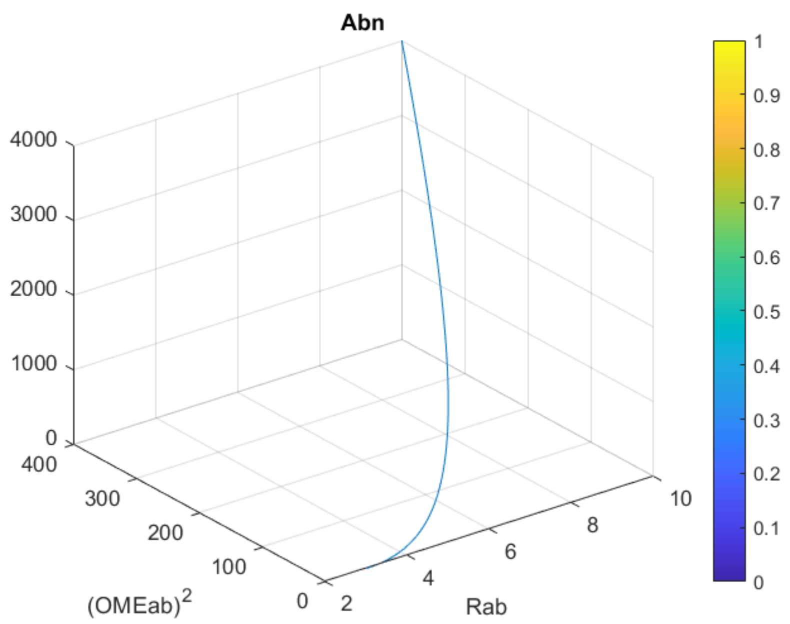

```
[Vbt,Vbn]=meshgrid(0:1:200,0:1:10);
VB=sqrt((Vbn).^2+(Vbt).^2);
mesh(Vbt,Vbn,VB)
colorbar
title('Velocity of point B')
xlabel('Vbt')
ylabel('Vbn')
```



```
"acceleration"
Abn=Rab.*(OMEab).^2;
max(Abn)
```

```
ans = 4000
```

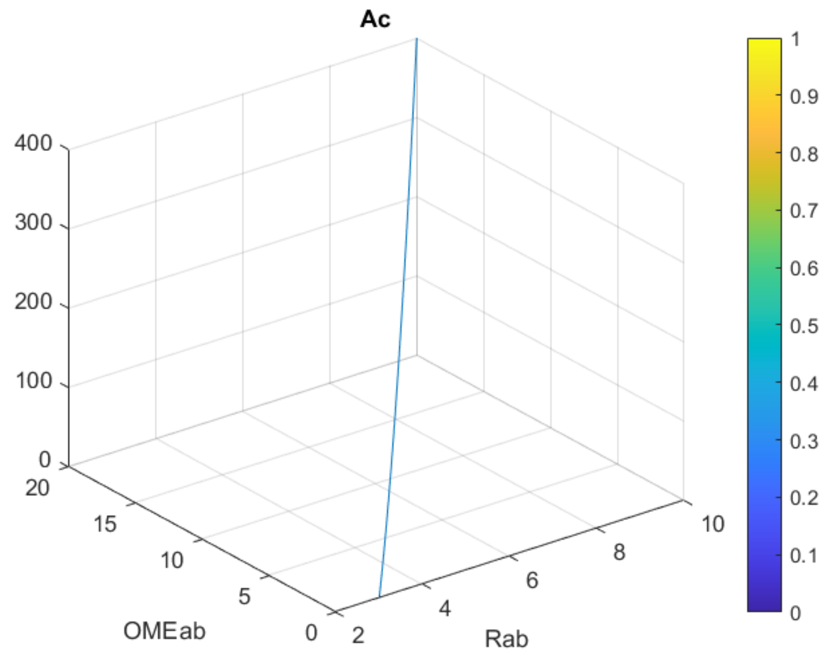
```
plot3(Rab,(OMEab).^2,Abn)
grid on
title('Abn')
xlabel('Rab')
ylabel('(OMEab)^2')
```




```
Ac=2*Rab.*OMEab;
max(Ac)
```

```
ans = 400
```

```
plot3(Rab,OMEab,Ac)
grid on
colorbar
title('Ac')
xlabel('Rab')
ylabel('OMEab')
```




```
[Abn,Ac]=meshgrid(0:1:4000,0:1:400);
Ab=sqrt((Abn).^2+(Ac).^2);
mesh(Abn,Ac,Ab)
title('Acceleration of point B')
xlabel('Ab')
ylabel('Ac')
colorbar
```