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Mechanics of Materials (7th Edition)

Chapter 7, Problem 2CP (4 Bookmarks) Show all steps: ON

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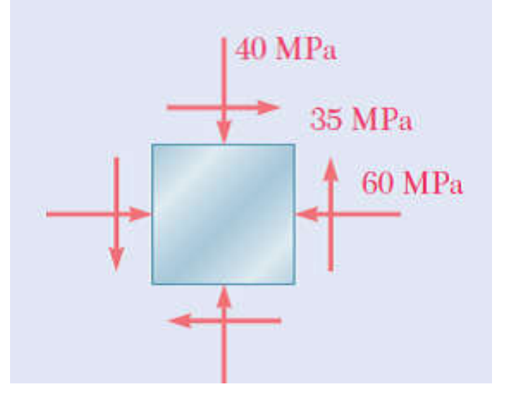
Problem

A state of plane stress is defined by the stress components σ_x, σ_y, and τ_{xy} associated with the element shown in Fig. P7.C1a. (*a*) Write a computer program that can be used to calculate the principal axes, the principal stresses, the maximum in-plane shearing stress, and the maximum shearing stress. (*b*) Use this program to solve Probs. 7.5, 7.9, 7.68, and 7.69.

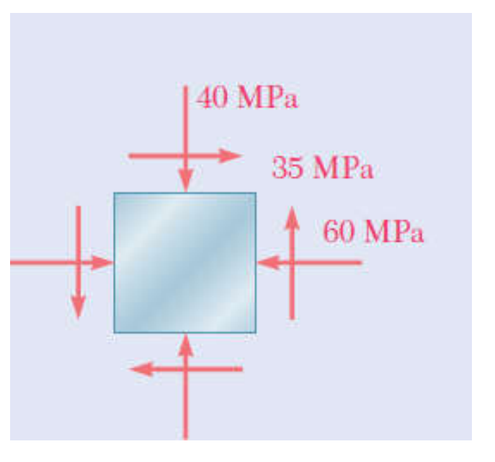
Reference 1:

For the given state of stress, determine (*a*) the principal planes, (*b*) the principal stresses.



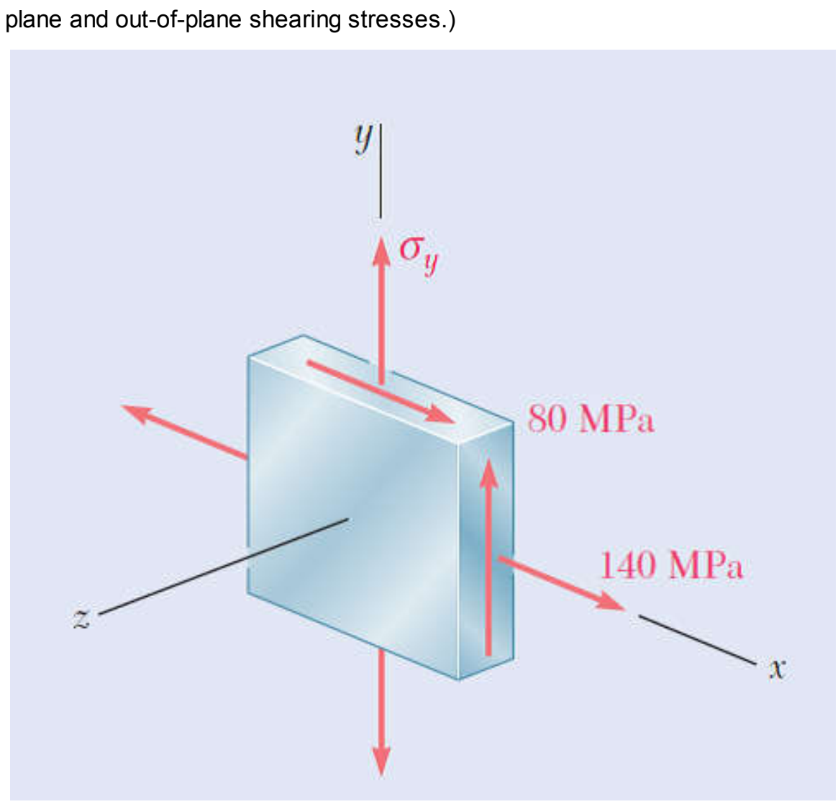
Reference 2:

For the given state of stress, determine (*a*) the orientation of the planes of maximum in-plane shearing stress, (*b*) the maximum in-plane shearing stress, (*c*) the corresponding normal stress.



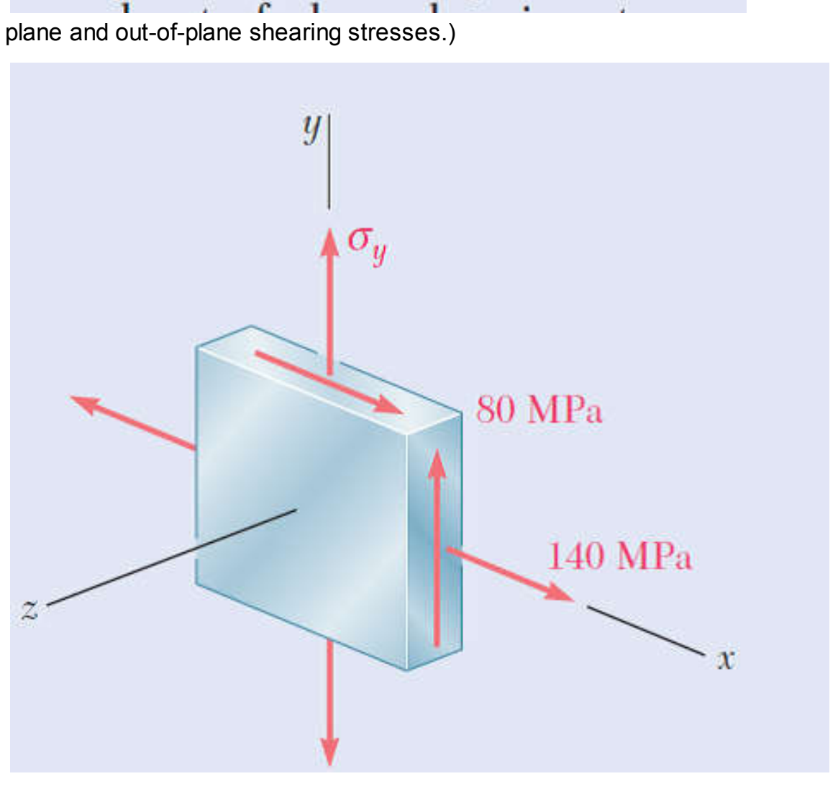
Reference 3:

For the state of stress shown, determine the maximum shearing stress when $(a)\ \sigma_y = 40\ \text{MPa},\ (b)\ \sigma_y = 120\ \text{MPa}.$ (*Hint:* Consider both in-plane and out-of-plane shearing stresses.)



Reference 4:

For the state of stress shown, determine the maximum shearing stress when $(a)\ \sigma_y = 20\ \text{MPa},\ (b)\ \sigma_y = 140\ \text{MPa}.$. (*Hint:* Consider both in-plane and out-of-plane shearing stresses.)

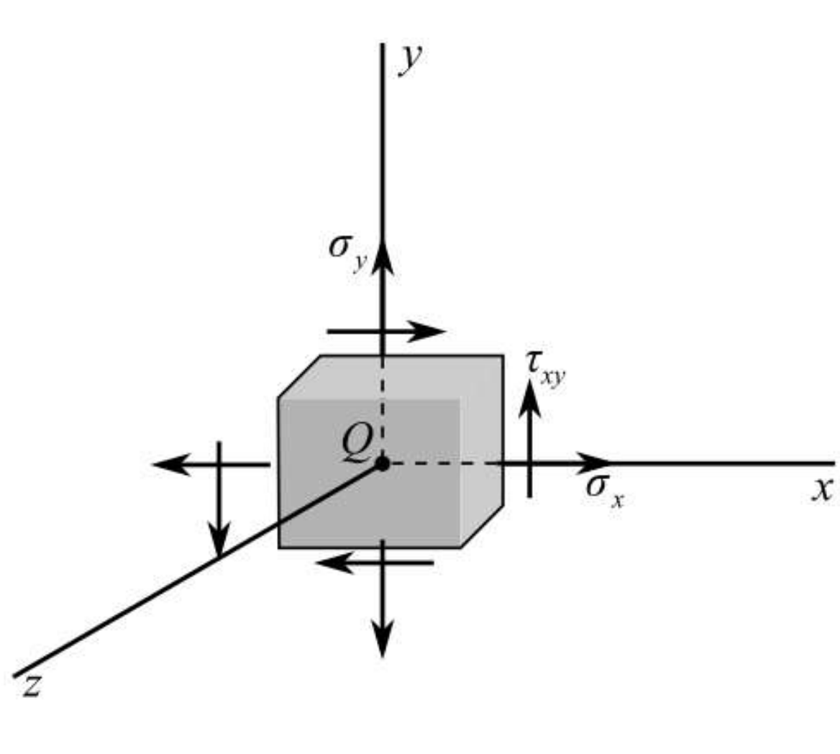


Step-by-step solution

Step 1 of 15

For an element under plane stress condition, the location of the principal axes $(\theta_p \text{ and } \theta_s)$, the principal stresses $(\sigma_{\max} \text{ and } \sigma_{\min})$, the maximum in-plane shearing stress $(\tau_{\max(\text{in-plane})})$, and the maximum shearing stress $(\tau_{\max(\text{out-of-plane})})$, are calculated at the surface of the element (shown in the figure below) as,

For the given stress element,



Comment

Step 2 of 15

To compute principal stress on the given stress element, average normal stress (σ_{avg}) and radius (R) of the Mohr circle are to be evaluated first, as,

Average normal stress (σ_{avg}) is calculated as,

$$\sigma_{\text{avg}} = \frac{\sigma_x + \sigma_y}{2} \quad \text{...... (1)}$$

Radius (R) of the Mohr circle is calculated as,

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \quad \text{...... (2)}$$

Comment

Step 3 of 15

Now, principal stresses $(\sigma_{\max} \text{ and } \sigma_{\min})$ that act on the stress element are evaluated (from equation 1, and 2) as,

Maximum principal stress $(\sigma_{\max})$ is calculated as,

$$\sigma_{\max} = \sigma_{\text{avg}} + R \quad \text{...... (3)}$$

Minimum principal stress $(\sigma_{\min})$ is calculated as,

$$\sigma_{\min} = \sigma_{\text{avg}} - R \quad \text{...... (4)}$$

Comment

Step 4 of 15

Principal planes are located the angle $(\theta_p \text{ and } \theta_s)$ as,

Angle between xy-axes and principal axes (that is, θ_p) is calculated as,

$$2\theta_p = \tan^{-1}\frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

Angle between xy-axes and planes of maximum in-plane shearing stress (that is, θ_s) is calculated as,

$$2\theta_s = \tan^{-1} - \frac{\sigma_x - \sigma_y}{2\tau_{xy}}$$

Comment

Step 5 of 15

Shearing stress conditions are evaluated to compute the maximum in-plane shearing stress $(\tau_{\max(\text{in-plane})})$ and the maximum shearing stress $(\tau_{\max(\text{out-of-plane})})$ as,

Case 1.

If, $\sigma_{\max} > 0$, and $\sigma_{\min} < 0$.

Then,

$\tau_{\max(\text{in-plane})} = R$, and

$\tau_{\max(\text{out-of-plane})} = R$

Case 2.

If, $\sigma_{\max} > 0$, and $\sigma_{\min} > 0$.

Then,

$\tau_{\max(\text{in-plane})} = R$, and

$\tau_{\max(\text{out-of-plane})} = \frac{\sigma_{\max}}{2}$

Case 3.

If, $\sigma_{\max} < 0$, and $\sigma_{\min} < 0$.

Then,

$\tau_{\max(\text{in-plane})} = R$, and

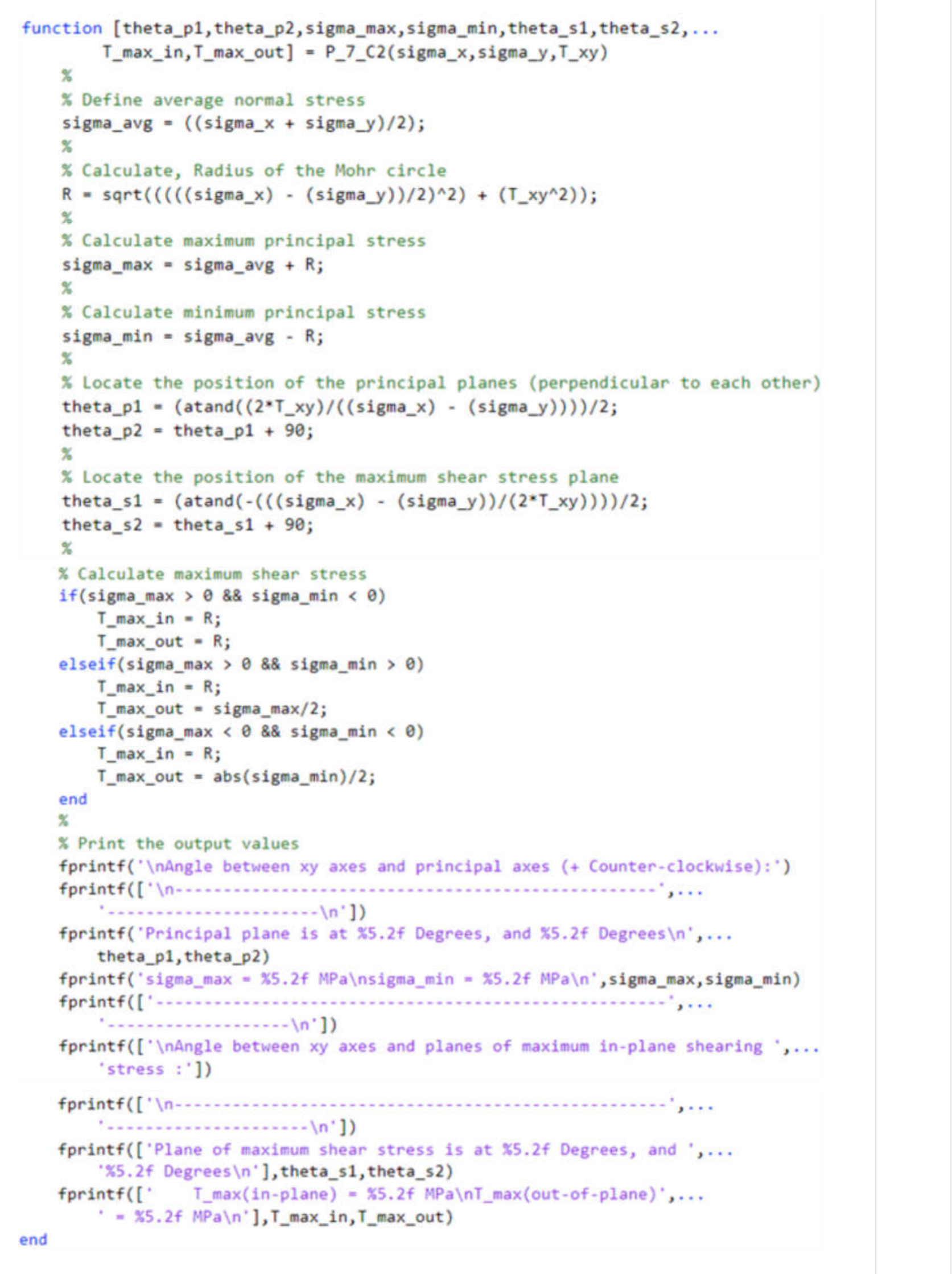
$\tau_{\max(\text{out-of-plane})} = \frac{1}{2}|\sigma_{\min}|$

Comment

Step 6 of 15

(a)

Type the following code in the **MATLAB** to obtain the solution for the provided questions.



```
function [theta_p1,theta_p2,sigma_max,sigma_min,theta_s1,theta_s2,...
        T_max_in,T_max_out] = P_7_C2(sigma_x,sigma_y,T_xy)
    %
    % Define average normal stress
    sigma_avg = ((sigma_x + sigma_y)/2);
    %
    % Calculate, Radius of the Mohr circle
    R = sqrt(((((sigma_x) - (sigma_y))/2)^2) + (T_xy^2));
    %
    % Calculate maximum principal stress
    sigma_max = sigma_avg + R;
    %
    % Calculate minimum principal stress
    sigma_min = sigma_avg - R;
    %
    % Locate the position of the principal planes (perpendicular to each other)
    theta_p1 = (atand((2*T_xy)/((sigma_x) - (sigma_y))))/2;
    theta_p2 = theta_p1 + 90;
    %
    % Locate the position of the maximum shear stress plane
    theta_s1 = (atand(-(((sigma_x) - (sigma_y))/(2*T_xy))))/2;
    theta_s2 = theta_s1 + 90;
    %
    % Calculate maximum shear stress
    if(sigma_max > 0 && sigma_min < 0)
        T_max_in = R;
        T_max_out = R;
    elseif(sigma_max > 0 && sigma_min > 0)
        T_max_in = R;
        T_max_out = sigma_max/2;
    elseif(sigma_max < 0 && sigma_min < 0)
        T_max_in = R;
        T_max_out = abs(sigma_min)/2;
    end
    %
    % Print the output values
    fprintf('\nAngle between xy axes and principal axes (+ Counter-clockwise):')
    fprintf(['\n-----------------------------------------------------',...
        '---------------------\n'])
    fprintf('Principal plane is at %5.2f Degrees, and %5.2f Degrees\n',...
        theta_p1,theta_p2)
    fprintf('sigma_max = %5.2f MPa\nsigma_min = %5.2f MPa\n',sigma_max,sigma_min)
    fprintf(['-----------------------------------------------------',...
        '-------------------\n'])
    fprintf(['\nAngle between xy axes and planes of maximum in-plane shearing ',...
        'stress :'])

    fprintf(['\n-----------------------------------------------------',...
        '---------------------\n'])
    fprintf(['Plane of maximum shear stress is at %5.2f Degrees, and ',...
        '%5.2f Degrees\n'],theta_s1,theta_s2)
    fprintf(['    T_max(in-plane) = %5.2f MPa\nT_max(out-of-plane)',...
        ' = %5.2f MPa\n'],T_max_in,T_max_out)
end
```

Comment

Step 7 of 15

Solution for Problem 7.5 and 7.9,

For given input parameters,

$\sigma_x = -60\ \text{MPa}$,

$\sigma_y = -40\ \text{MPa}$, and

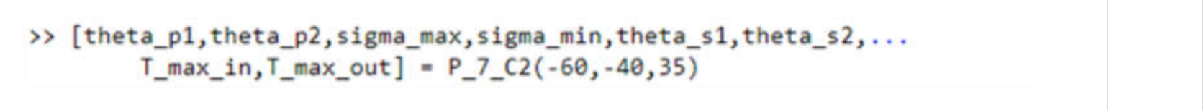
$\tau_{xy} = 35\ \text{MPa}$

Comment

Step 8 of 15

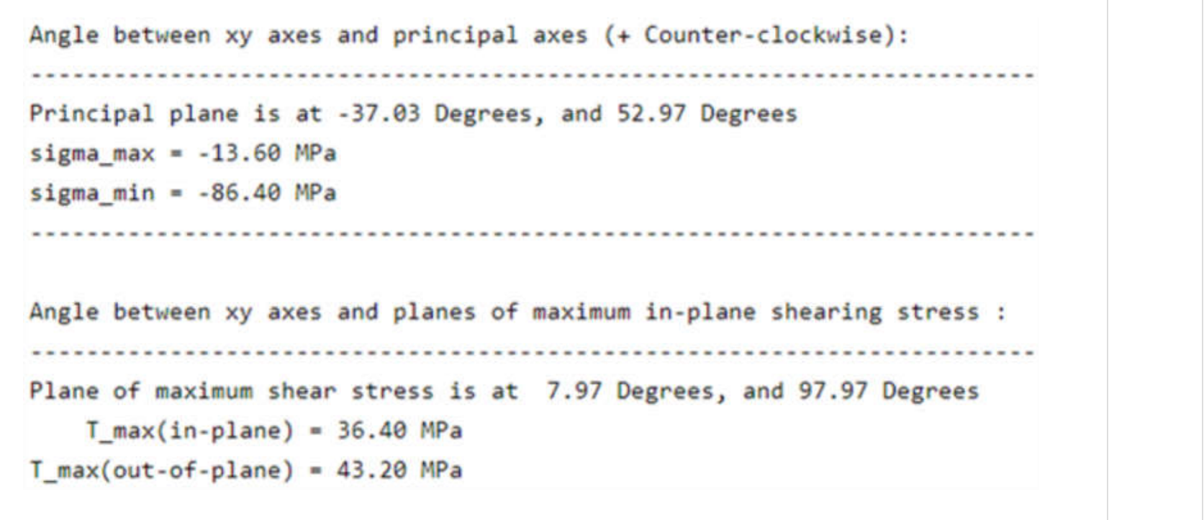
Execute the MATLAB code, to obtain the output for the given problem as,

Type following input in the command window.



```
>> [theta_p1,theta_p2,sigma_max,sigma_min,theta_s1,theta_s2,...
        T_max_in,T_max_out] = P_7_C2(-60,-40,35)
```

The obtained result for the provided values is,



```
Angle between xy axes and principal axes (+ Counter-clockwise):
--------------------------------------------------------------------------
Principal plane is at -37.03 Degrees, and 52.97 Degrees
sigma_max = -13.60 MPa
sigma_min = -86.40 MPa
--------------------------------------------------------------------------

Angle between xy axes and planes of maximum in-plane shearing stress :
--------------------------------------------------------------------------
Plane of maximum shear stress is at  7.97 Degrees, and 97.97 Degrees
    T_max(in-plane) = 36.40 MPa
T_max(out-of-plane) = 43.20 MPa
```

Comment

Step 9 of 15

Solution for Problem 7.68,

For given input parameters,

$\sigma_x = 140\ \text{MPa}$,

$\sigma_y = 40\ \text{MPa}$, and

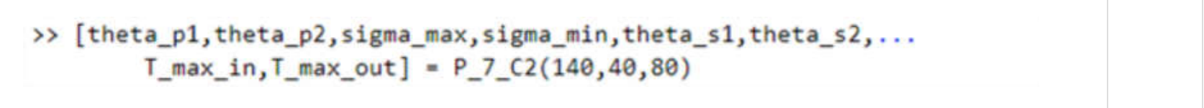
$\tau_{xy} = 80\ \text{MPa}$

Comment

Step 10 of 15

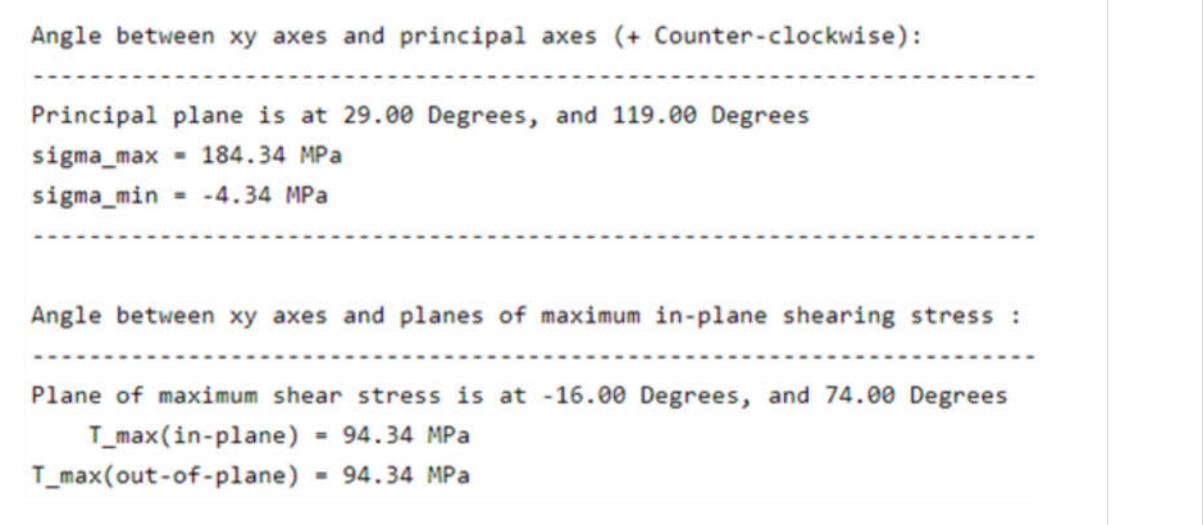
Execute the MATLAB code, to obtain the output for the given problem as,

Type following input in the command window.



```
>> [theta_p1,theta_p2,sigma_max,sigma_min,theta_s1,theta_s2,...
        T_max_in,T_max_out] = P_7_C2(140,40,80)
```

The obtained result for the provided values is,



```
Angle between xy axes and principal axes (+ Counter-clockwise):
--------------------------------------------------------------------------
Principal plane is at 29.00 Degrees, and 119.00 Degrees
sigma_max = 184.34 MPa
sigma_min = -4.34 MPa
--------------------------------------------------------------------------

Angle between xy axes and planes of maximum in-plane shearing stress :
--------------------------------------------------------------------------
Plane of maximum shear stress is at -16.00 Degrees, and 74.00 Degrees
    T_max(in-plane) = 94.34 MPa
T_max(out-of-plane) = 94.34 MPa
```

Comment

Step 11 of 15

For given input parameters,

$\sigma_x = 140\ \text{MPa}$,

$\sigma_y = 120\ \text{MPa}$, and

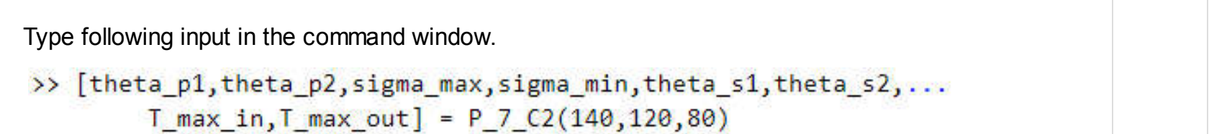
$\tau_{xy} = 80\ \text{MPa}$

Comment

Step 12 of 15

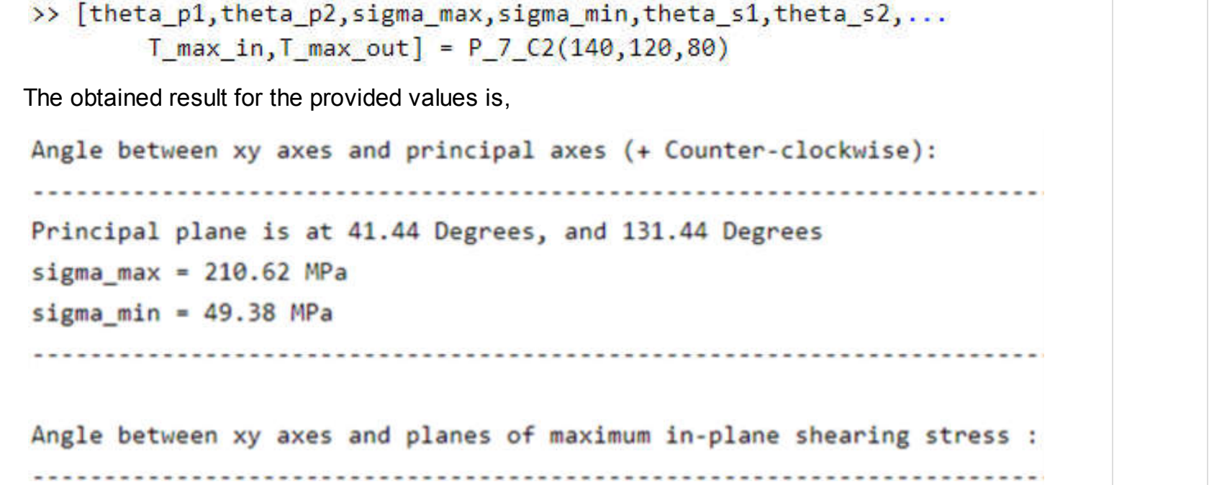
Execute the MATLAB code, to obtain the output for the given problem as,

Type following input in the command window.



```
>> [theta_p1,theta_p2,sigma_max,sigma_min,theta_s1,theta_s2,...
        T_max_in,T_max_out] = P_7_C2(140,120,80)
```

The obtained result for the provided values is,



```
Angle between xy axes and principal axes (+ Counter-clockwise):
--------------------------------------------------------------------------
Principal plane is at 41.44 Degrees, and 131.44 Degrees
sigma_max = 210.62 MPa
sigma_min = 49.38 MPa
--------------------------------------------------------------------------

Angle between xy axes and planes of maximum in-plane shearing stress :
--------------------------------------------------------------------------
Plane of maximum shear stress is at -3.56 Degrees, and 86.44 Degrees
    T_max(in-plane) = 80.62 MPa
T_max(out-of-plane) = 105.31 MPa
```

Comment

Step 13 of 15

Solution for Problem 7.69,

For given input parameters,

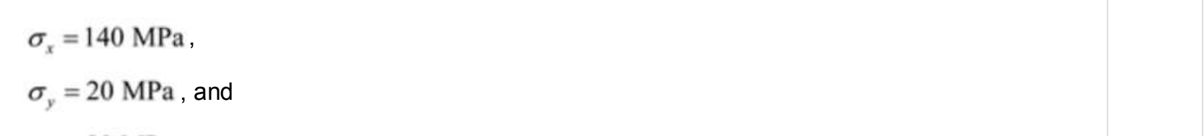
$\sigma_x = 140\ \text{MPa}$,

$\sigma_y = 20\ \text{MPa}$, and

$\tau_{xy} = 80\ \text{MPa}$

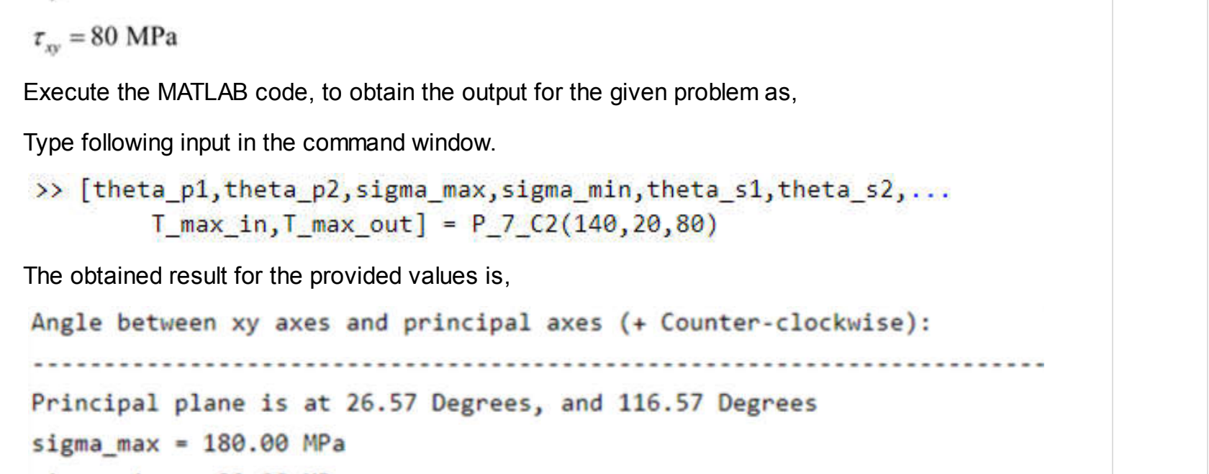
Execute the MATLAB code, to obtain the output for the given problem as,

Type following input in the command window.



```
>> [theta_p1,theta_p2,sigma_max,sigma_min,theta_s1,theta_s2,...
        T_max_in,T_max_out] = P_7_C2(140,20,80)
```

The obtained result for the provided values is,



```
Angle between xy axes and principal axes (+ Counter-clockwise):
--------------------------------------------------------------------------
Principal plane is at 26.57 Degrees, and 116.57 Degrees
sigma_max = 180.00 MPa
sigma_min = -20.00 MPa
--------------------------------------------------------------------------

Angle between xy axes and planes of maximum in-plane shearing stress :
--------------------------------------------------------------------------
Plane of maximum shear stress is at -18.43 Degrees, and 71.57 Degrees
    T_max(in-plane) = 100.00 MPa
T_max(out-of-plane) = 100.00 MPa
```

Comment

Step 14 of 15

For given input parameters,

$\sigma_x = 140\ \text{MPa}$,

$\sigma_y = 140\ \text{MPa}$, and

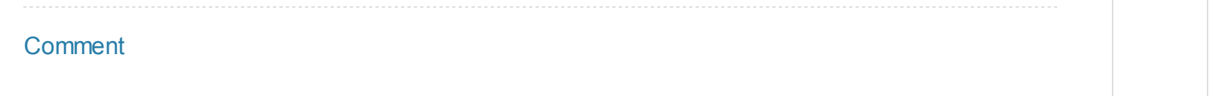
$\tau_{xy} = 80\ \text{MPa}$

Comment

Step 15 of 15

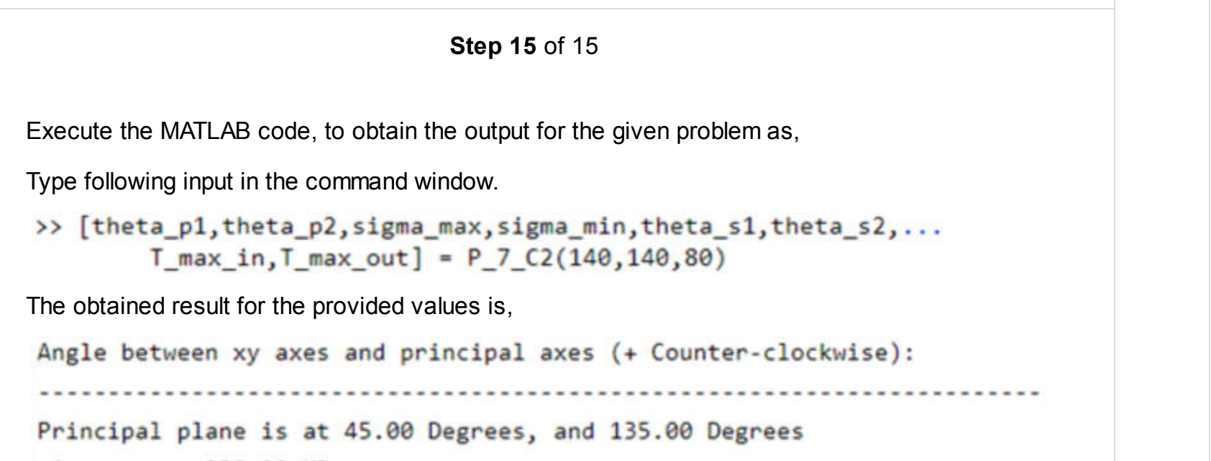
Execute the MATLAB code, to obtain the output for the given problem as,

Type following input in the command window.



```
>> [theta_p1,theta_p2,sigma_max,sigma_min,theta_s1,theta_s2,...
        T_max_in,T_max_out] = P_7_C2(140,140,80)
```

The obtained result for the provided values is,



```
Angle between xy axes and principal axes (+ Counter-clockwise):
--------------------------------------------------------------------------
Principal plane is at 45.00 Degrees, and 135.00 Degrees
sigma_max = 220.00 MPa
sigma_min = 60.00 MPa
--------------------------------------------------------------------------

Angle between xy axes and planes of maximum in-plane shearing stress :
--------------------------------------------------------------------------
Plane of maximum shear stress is at -0.00 Degrees, and 90.00 Degrees
    T_max(in-plane) = 80.00 MPa
T_max(out-of-plane) = 110.00 MPa
```

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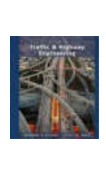

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