

Mechanics of Materials | (7th Edition)

Chapter 6, Problem 3CP

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Problem

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beam having the cross section shown is subjected to a vertical shear V . Write a computer program that, for loads and dimensions expressed in either SI or U.S. customary units, can be used to calculate the shearing stress along the line between any two adjacent rectangular areas forming the cross section. Use this program to solve (a) Prob. 6.10, (b) Prob. 6.12, (c) Prob. 6.22.

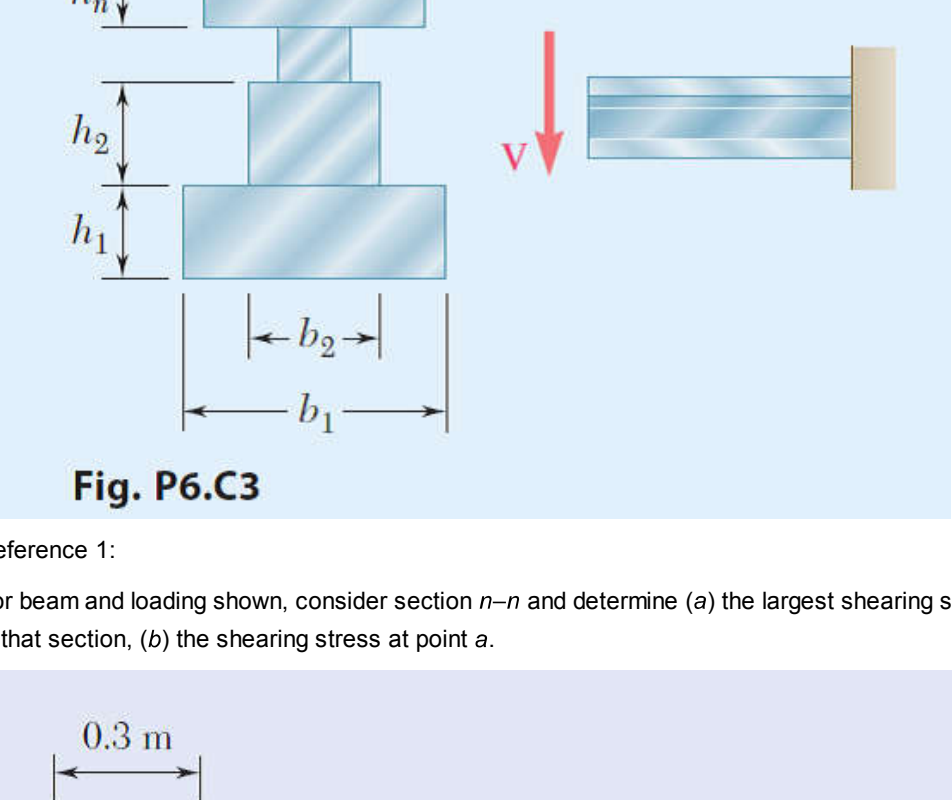
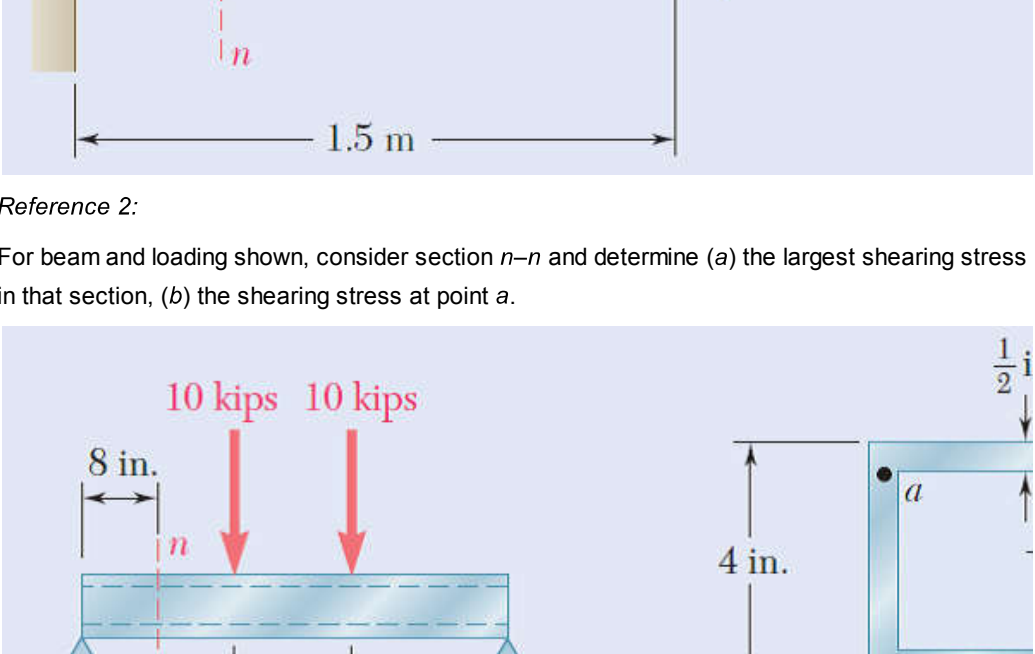


Fig. P6.C3

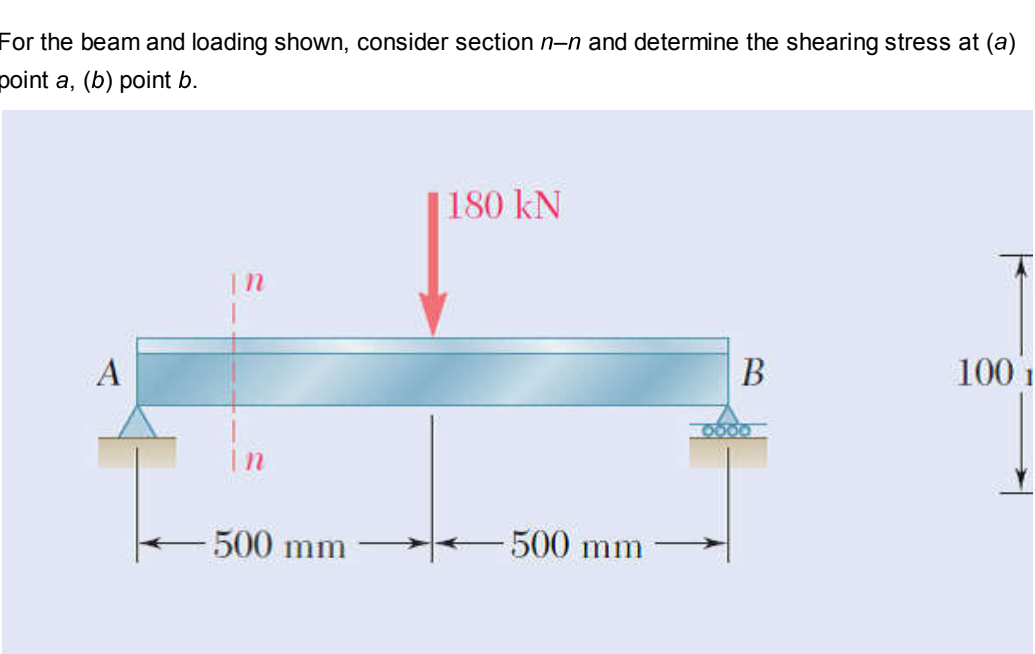
Reference 1:

For beam and loading shown, consider section $n-n$ and determine (a) the largest shearing stress in that section, (b) the shearing stress at point a .



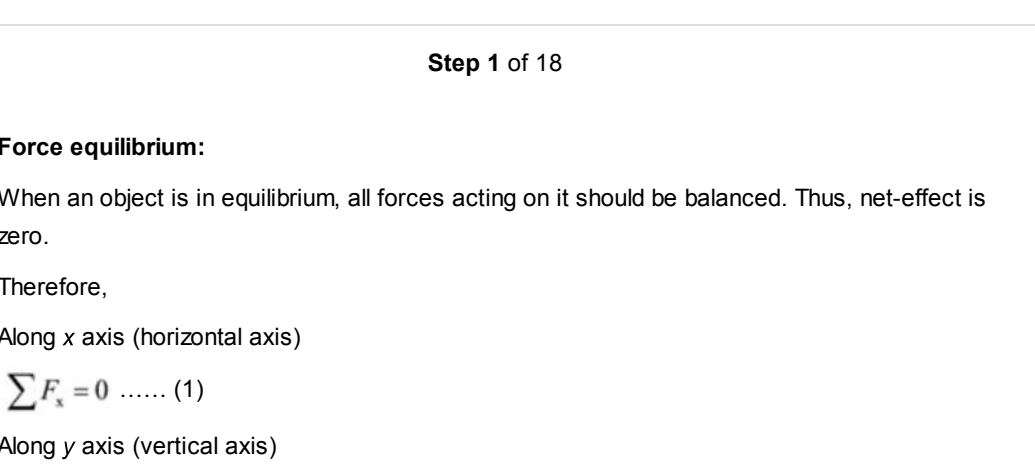
Reference 2:

For beam and loading shown, consider section $n-n$ and determine (a) the largest shearing stress in that section, (b) the shearing stress at point a .



Reference 3:

For the beam and loading shown, consider section $n-n$ and determine the shearing stress at (a) point a , (b) point b .



Step-by-step solution

Step 1 of 18

Force equilibrium:

When an object is in equilibrium, all forces acting on it should be balanced. Thus, net-effect is zero.

Therefore,

Along x axis (horizontal axis)

$$\sum F_x = 0 \quad \text{..... (1)}$$

Along y axis (vertical axis)

$$\sum F_y = 0 \quad \text{..... (2)}$$

First area moment (Q_x) of an elemental area (dA) about x axis is expressed as,

$$Q_x = \int y dA \quad \text{..... (3)}$$

Here y is the distance of the elemental area from the x axis.

Second area moment or, area moment of inertia (I) calculated about the axis passing through the centroid of the rectangular cross-section bar and crossing the height (h) of the section is expressed as,

$$I = \frac{bh^3}{12} \quad \text{..... (4)}$$

Here b is the width of the rectangular cross-section.

Area moment of inertia (I) about an axis parallel to the centroidal axis, but not passing through the centroid is calculated from the parallel axis theorem as,

$$I = I_c + Ad^2 \quad \text{..... (5)}$$

Here, A is the surface area, d is the separation distance between the given axis about which the area moment of inertia is to be calculated and the axis passing through the centroid and parallel to the given axis, and I_c is the area moment of inertia about an axis passing through the centroid.

y coordinate of the centroid of any given area is calculated as,

$$\bar{y} = \frac{\int y dA}{\int dA} \quad \text{..... (6)}$$

Here y is the distance of the elemental area (dA) from the x axis of a given coordinate system, $\int dA$ represents the total area.

Transverse shear stress (τ) is calculated as,

$$\tau = \frac{QV}{I t} \quad \text{..... (7)}$$

Here, I is area moment of inertia of the given section, Q is the first area moment of the element at which stress is to be calculated, t is the width of the element at which stress is to be calculated, and V is the applied shear force.

General sign convention for the axis: Distance along the axis is considered as positive, while the distance measured in a direction opposite to the axis is considered as negative.

Comment

Step 2 of 18

Consider the equations written below for the MATLAB program.

To solve for the stress at any section, divide the given cross-section into small rectangles, such that combined effect of all these rectangles result into the given cross-section.

For a given shear force (V) and the number of rectangles (n) that form the given cross-section of the beam, define the dimension (b_i and h_i) of the rectangles. Here, b_i denotes the breadth of the rectangle, h_i denotes the height of the rectangle and subscript i represents the i^{th} rectangle.

Now compute the area (A_i) of each rectangle as,

$$A_i = b_i h_i \quad \text{..... (8)}$$

The elevation (from the bottom) of centroid ($\bar{y}_i$) of each rectangle is calculated as,

$$\bar{y}_i = \sum_{j=1}^i \frac{h_j}{2} \quad \text{..... (9)}$$

Here, $\sum_{j=1}^i h_j$ represents total height from the bottom, upto the top edge of i^{th} rectangle.

Centroid ($\bar{y}$) of the entire section of the given beam is calculated (from equation 6) as,

$$\bar{y} = \frac{\sum \bar{y}_i A_i}{\sum A_i} \quad \text{..... (10)}$$

Comment

Step 3 of 18

Now consider all the rectangles to calculate (from equation 4 and 5) the moment of inertia about neutral axis passing through the centroid of the given section as,

$$I = \sum \left(\frac{b_i h_i^3}{12} + A_i (\bar{y}_i - \bar{y})^2 \right) \quad \text{..... (11)}$$

Calculate the first area moment (Q_x) of the area below the surface separating i^{th} and $(i+1)^{\text{th}}$ rectangles as,

$$Q_x = A_i (\bar{y}_i - \bar{y}) \quad \text{..... (12)}$$

Comment

Step 4 of 18

Now, to calculate the transverse shear stress (τ_i) at a section between i^{th} and $(i+1)^{\text{th}}$ rectangles, select the width t_i (smaller of breadth b_i and b_{i+1}) and solve as,

$$\tau_i = \frac{QV}{I t_i} \quad \text{..... (13)}$$

Comment

Step 5 of 18

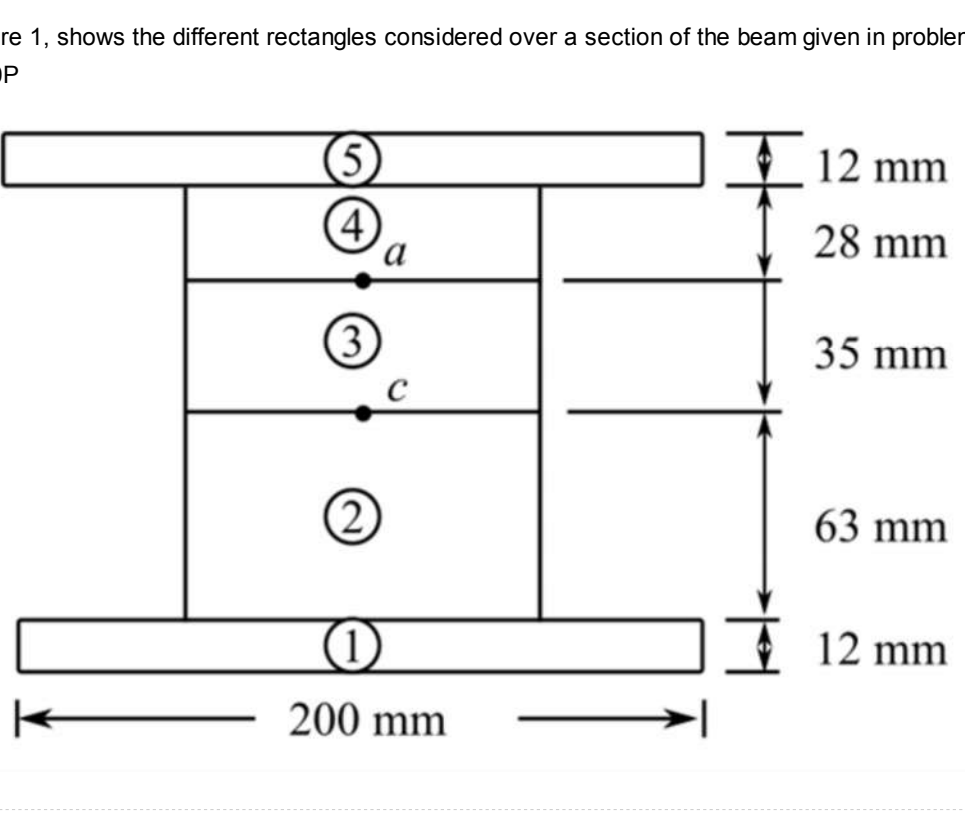
Type the following code in the MATLAB to obtain the solution for the provided question.

```
% Take user input.
V = input('Value of the Vertical Shear force in [N] : ');
n = input('Enter the number of Rectangles : ');
H = 0;
At = 0;
a = 0;
I = 0;
for i=1:n
    fprintf('Breadth of the Rectangle %i in [mm] : ',i);
    b(i) = input(' ');
    fprintf('Height of the Rectangle %i in [mm] : ',i);
    h(i) = input(' ');
    H = H+h(i);
    A(i) = (b(i)*h(i));
    At = (At+A(i));
    y(i) = H-(0.5*h(i));
    a = a+(A(i)*y(i));
    V_Bar = (a/At);
end
fprintf('\nApplied shear force, \nV = %2.2f kN/\n\n', V/1000);
fprintf(['Y-coordinate of the centroid for given ', ...
'cross-section, \nV_Bar = %2.2f mm (above the base)\n' ...
'\n Bar:']);
for i=1:n
    I = I+((b(i)*h(i)^3)/12+(A(i)*(y(i)-V_Bar)^2));
end
fprintf('\ndarea moment of inertia, \nI = %2.2f mm^4\n\n', I);
for i=1:n
    Q(i) = (A(i)*(y(i)-V_Bar));
end
for i=1:n-1
    if b(i)<=b(i+1)
        t=b(i);
    else
        t=b(i+1);
    end
    Tau(i) = (V*Q(i))/(I*t);
end
e = 0;
for i=1:n-1
    if i%2
        e = e+Tau(i);
    else
        e = e-Tau(i);
    end
    fprintf(['Shear stress between elements %d and ', ...
'\n %d : \nTau = %3.3f MPa\n\n'], i, i+1, e);
end
```

Comment

Step 6 of 18

(a)
Figure 1, shows the different rectangles considered over a section of the beam given in problem 6.10P



Comment

Step 7 of 18

Execute the MATLAB code with the following input data to solve the problem 6.10P as,

From force equilibrium in vertical direction, force at section $n-n$, (that is applied shear force) is given as,

$$V = 10000 \text{ N}$$

Consider 5 rectangles as shown in Figure 1. Thus,

$$n = 5$$

Consider the dimensions (breadth (b) and height (h)) for the 5 rectangles (refer Figure 1) as,

For rectangle 1,

$$b_1 = 200 \text{ mm}$$

$$h_1 = 12 \text{ mm}$$

Comment

Step 8 of 18

For rectangle 2,

$$b_2 = 100 \text{ mm}$$

$$h_2 = 63 \text{ mm}$$

For rectangle 3,

$$b_3 = 100 \text{ mm}$$

$$h_3 = 35 \text{ mm}$$

For rectangle 4,

$$b_4 = 100 \text{ mm}$$

$$h_4 = 28 \text{ mm}$$

For rectangle 5,

$$b_5 = 200 \text{ mm}$$

$$h_5 = 12 \text{ mm}$$

Comment

Step 9 of 18

Now, execute the MATLAB code and enter the input values, to obtain the output for the given problem as,

```
>> P6_C3
Value of the Vertical Shear force in [N] :
10000
Enter the Number of Rectangles :
5
Breadth of the Rectangle 1 in [mm] :
200
Height of the Rectangle 1 in [mm]:
12
Breadth of the Rectangle 2 in [mm] :
100
Height of the Rectangle 2 in [mm]:
63
Breadth of the Rectangle 3 in [mm] :
100
Height of the Rectangle 3 in [mm]:
35
Breadth of the Rectangle 4 in [mm] :
100
Height of the Rectangle 4 in [mm]:
28
Breadth of the Rectangle 5 in [mm] :
200
Height of the Rectangle 5 in [mm]:
12

Applied shear force,
V = 10.00 kN

Y-coordinate of the centroid for given cross-section,
V_Bar = 75.00 mm (above the base)

Area moment of inertia,
I = 39580200.00 mm^4

Shear stress between elements 1 and 2 :
Tau = 0.418 MPa

Shear stress between elements 2 and 3 :
Tau = 0.920 MPa

Shear stress between elements 3 and 4 :
Tau = 0.765 MPa

Shear stress between elements 4 and 5 :
Tau = 0.418 MPa
```

Comment

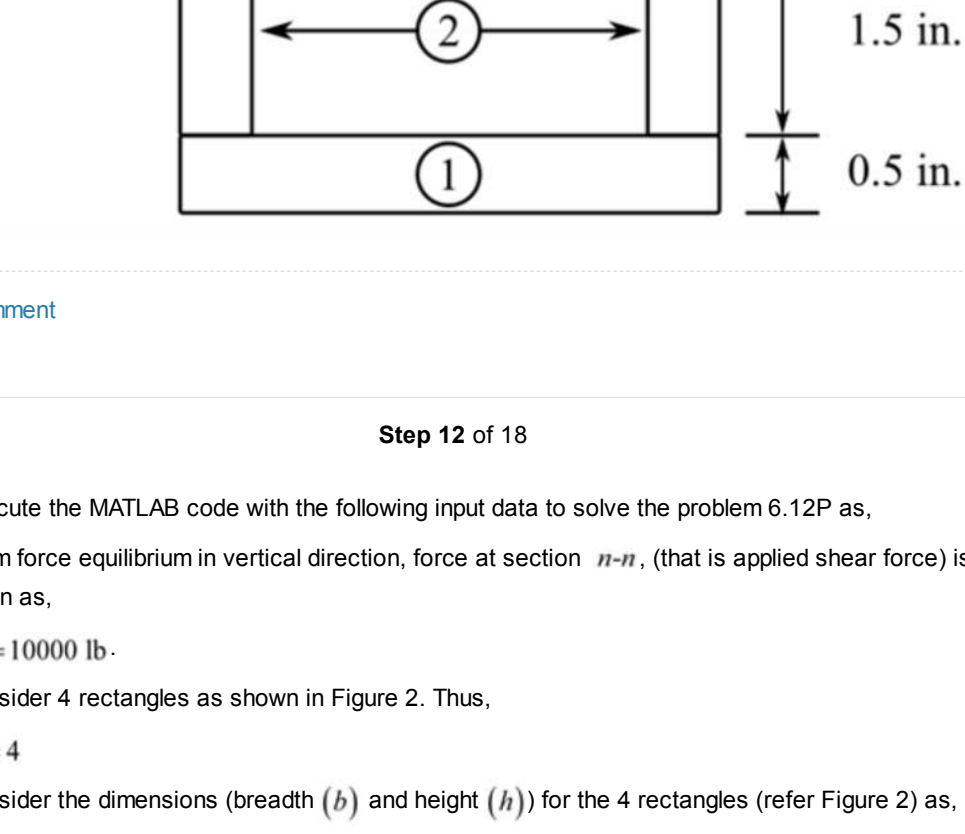
Step 10 of 18

Thus, maximum shearing stress is 0.92 MPa , and shearing stress at point a is 0.765 MPa .

Comment

Step 11 of 18

(b)
Figure 2, shows the different rectangles considered over a section of the beam given in problem 6.12P



Comment

Step 12 of 18

Execute the MATLAB code with the following input data to solve the problem 6.12P as,

From force equilibrium in vertical direction, force at section $n-n$, (that is applied shear force) is given as,

$$V = 10000 \text{ lb}$$

Consider 4 rectangles as shown in Figure 2. Thus,

$$n = 4$$

Consider the dimensions (breadth (b) and height (h)) for the 4 rectangles (refer Figure 2) as,

For rectangle 1,

$$b_1 = 4 \text{ in}$$

$$h_1 = 0.5 \text{ in}$$

For rectangle 2,

$$b_2 = 1 \text{ in}$$

$$h_2 = 1.5 \text{ in}$$

For rectangle 3,

$$b_3 = 1 \text{ in}$$

$$h_3 = 1.5 \text{ in}$$

For rectangle 4,

$$b_4 = 4 \text{ in}$$

$$h_4 = 0.5 \text{ in}$$

Comment

Step 13 of 18

Now, before executing the code, modify the code to incorporate the changes in units as, shown below,

Post a question

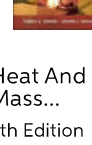
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