بسم الله الرحمن الرحيم

King Abdulaziz University
Engineering College
Department of Production and Mechanical System Design

MENG 270 Mechanics of Materials

Final Exam
Wednesday: 22/11/1424 H
Time Allowed: Two Hours

Name:	Sec. No.:	ID No.:

Question 1		10
Question 2		10
Question 3		10
Question 4		10
Question 5		10
Question 6		10
TOTAL		60

إن اللهَ يُمْسِكُ السمَاوَاتِ وَالأَرْضَ أن تَزُولا وَلَئِن زَالَتَا إنْ أَمْسَكَهُمَا مِنْ أحَدٍ من بَعْدِهِ
إنهُ كَانَ حَليماً غَفُورا

Instructions

1. There are totally 6 problems in this exam.
2. Show all work for partial credit.
3. Assemble your work for each problem in logical order.
4. Justify your conclusion. I cannot read minds.

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Mechanics of Materials	Closed-book Exam
MENG270	Time one hour
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Student Name:			Sec. No.:	ID No.:
Q1: /10		Q2: /10		Q3: /10

1. Are these statements **true** or **false**?

		True	False
a.	The shear strain in a rod is the deformation per unit length	☐	■
b.	The Hook's law states that for small deformations the stress is directly proportional to the strain.	■	☐
c.	The ratio of the lateral strain over the axial strain is called *Poisson's ratio*.	■	☐
d.	The hoop stress of spherical thin-walled pressure vessels is twice as large as the longitudinal stress.	☐	■
e.	Ductile materials are characterized by the fact that, when subjected to a tensile test, they fail suddenly through fracture without any prior yielding.	☐	■
f.	The failure criterion most frequently used for brittle materials is the maximum-shear-stress criterion.	☐	■
g.	The plane of maximum shearing stress is at 45 degree to the principal plane.	■	☐
h.	The beam which has a fixed end at $x=0$ and is supported by a roller at $x=L$ is statically indeterminate.	■	☐
i.	If the stress on a transverse section of a column is less than the allowable strength then you can conclude that the column has been properly designed.	■	☐
j.	The strain energy density is equal to the area under the load-deformation diagram.	☐	■

2. A beam is constructed by gluing three long, rectangular x-cross section piece of wood so that the resulting x-section is as shown below in Figure (1a). The loading is such that, at a particular transverse section, the internal shear force and the bending moment are as shown in Figure (1b).

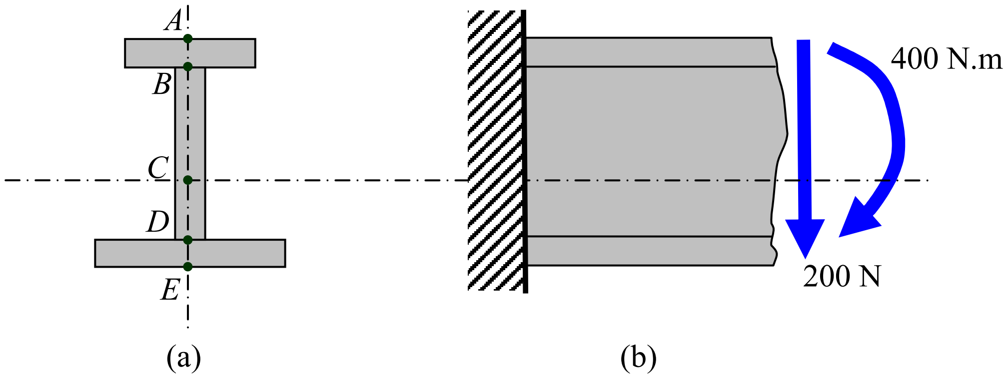


Figure (1)

Use the point labeled on Figure (1a) to complete the statement below. (There may be more than one answer for each statement):

a) Zero normal stress occurs at Point(s) ___C___.

b) Zero shear stress occurs at Point(s) ___E, A___.

c) Maximum compressive stress occurs at Point(s) ___E___.

d) Maximum shear stress occurs at Point(s) ___C___.

e) Maximum tensile stress occurs at Point(s) ___A___.

3. The beam ABCD is loaded by a force W=30 KN by the arrangement shown in the Figure (2). The cable passes over a small frictionless pulley at B and is attached at E to the vertical arm. Calculate the following:

a) The reaction forces at A and D.
b) The axial forces N at section C, which is just to the left of the vertical arm.
c) The shear force V at section C.
d) The bending moment M at section C.

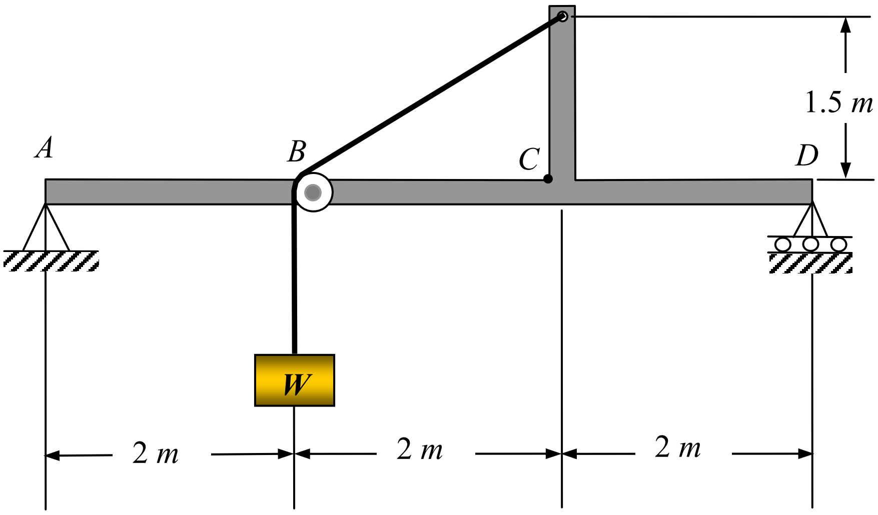
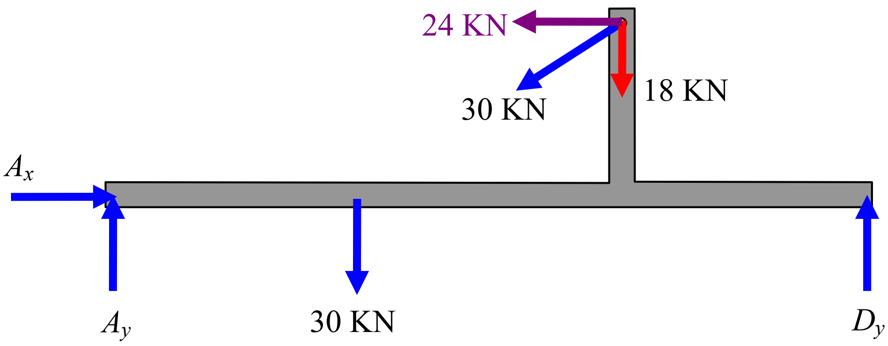
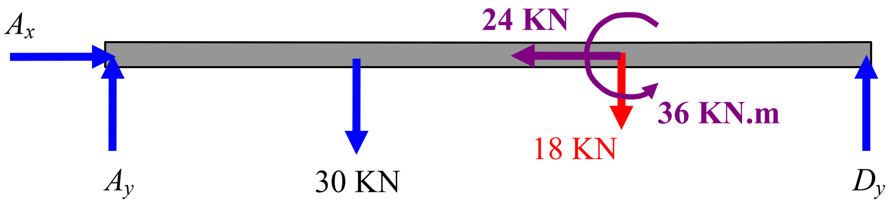


Figure (2)

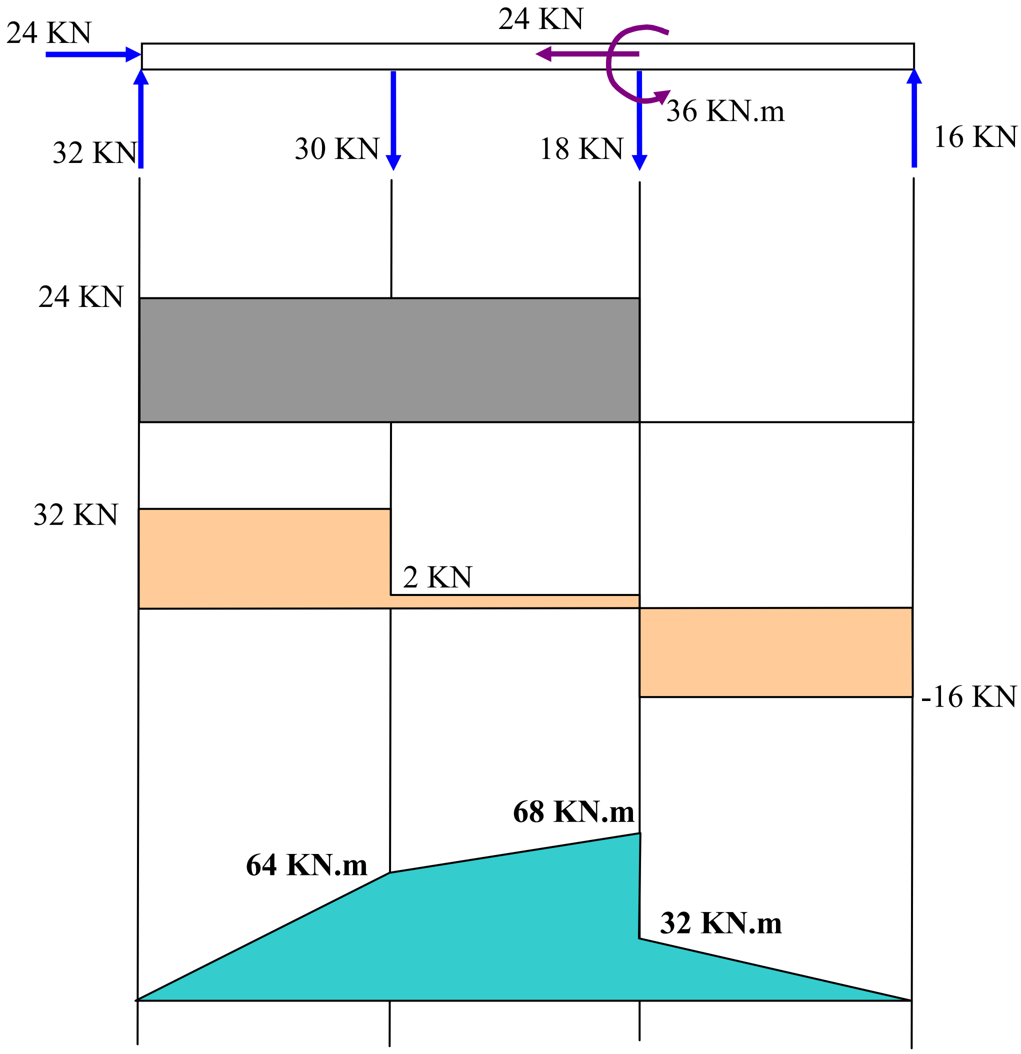




Solution

$$\sum F_x = 0: \qquad A_x = 24 \text{ KN}$$
$$\sum F_y = 0: \qquad A_y + D_y = 48 \text{ KN}$$
$$\sum M_A = 0: \qquad -30(2) - 18(4) + 36 + D_y(6) = 0$$

$$D_y = 16 \text{ KN} \quad \text{and} \quad A_y = 32 \text{ KN}$$



Answers:

a) $A_x = 24$ KN , $A_y = 20$ KN , and $D_y = 28$ KN .

b) N=24 KN.

c) V=2 KN.

d) M=68 KN.

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Q4:	/10	Q5:	/10	Q6:	/10

4. Each member of the truss shown in Figure (3) is made of aluminum (E= 72 GPa). If the cross section area of the member BC is 2000 mm^2 and of the member CD is 2500 mm^2. Determine the strain energy of the truss.

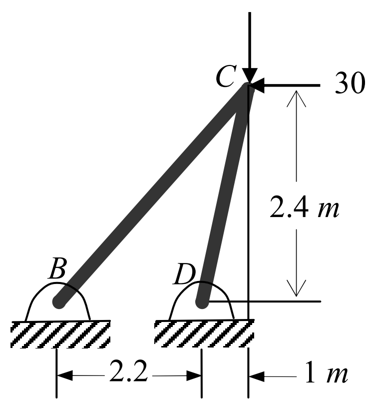


Figure (3)

Solution

Strain Energy of the truss is given by

$$\sum \frac{F_i^2 L_i}{2A_i E}$$

Where, F_i is the force in a given member under the combined loading.

Forces in members

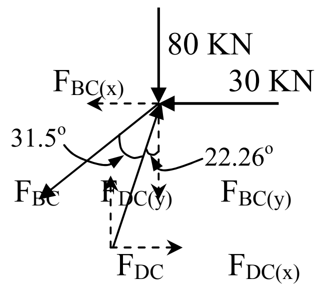
Consider the equilibrium of joint C as shown in Figure (a)

$F_{BC(x)} = F_{BC} \cos 36.87 = 0.8F_{BC}$

$F_{BC(y)} = F_{BC} \sin 36.87 = 0.6\ F_{BC}$

$F_{DC(x)} = F_{DC} \sin 22.6 = 0.385\ F_{DC}$

$F_{DC(y)} = F_{DC} \cos 22.62 = 0.923\ F_{DC}$



$\Sigma F_x = 0$

$$F_{DC(x)} - F_{BC(x)} - 30 = 0$$

$$0.385\ F_{DC} - 0.8\ F_{BC} = 30 \qquad (1)$$

$\Sigma F_y = 0$

Figure (a)

$$F_{DC(y)} - F_{BC(y)} - 80 = 0$$

$$0.923\ F_{DC} - 0.6\ F_{BC} = 80 \qquad (2)$$

Solving equations (1) & (2)

$F_{BC} = 6.127$ kN
$F_{DC} = 90.65$ kN

Length of members

$$L_{BC} = \sqrt{2.4^2 + 3.2^2} = 4\ m$$

$$L_{DC} = \sqrt{2.4^2 + 1^2} = 2.6\,m$$

Strain Energy

$U = U_{BC} + U_{DC}$

$$U = \frac{F_{BC}^2\,L_{BC}}{2\,A_{BC}\,E} + \frac{F_{DC}^2\,L_{DC}}{2\,A_{DC}\,E}$$

$$U = \frac{\left(6.127\times10^3\right)^2\times4}{2\times2000\times10^{-6}\times72\times10^9} + \frac{\left(90.65\times10^3\right)^2\times2.6}{2\times2500\times10^{-6}\times72\times10^9}$$

$U = 59.8$ J

5. Beam *CE* rests on beam AB as shown in Figure (4). Knowing that a W 250 x 49.1 rolled steel shape is used for each beam (E = 200 GPa), determine the following:

a) The deflection at point D due to point load on beam CE.
b) Forces acting on beam AB.
c) Deflection at point C on beam AB.
d) Total deflection at point D.

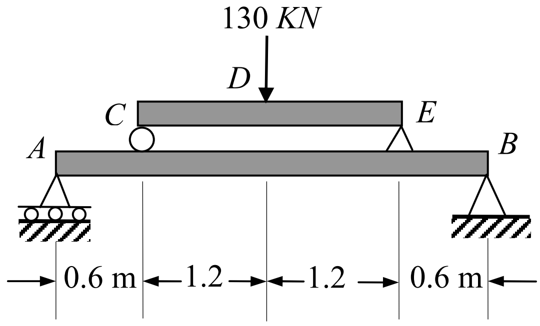


Figure (4)

Solution

(a) For convenience let us split the given structure into two parts as shown in figure
A little consideration will show that the deflection y_D at point D will be equal to
y_D = Deflection of beam CD due to load 130 kN at D+ Deflection of beam AB due
combined loading at point C.

Deflection of beam CD

Let us consider simply supported beam CD, with point load 130 kN at point D.

a=1.2 m ; b= 1.2 m ; L = 2.4 m ; x= L/2 ;
I = 70.8 x 10^{-6} m^4 (from table)

Using relation,

$$y_1 = \frac{PL^3}{48EI}$$

$$y_1 = \frac{130\times1000\times2.4^3}{48\times200\times10^9\times70.8\times10^{-6}} = 0.002644\,m$$

y_1 = 2.644 mm

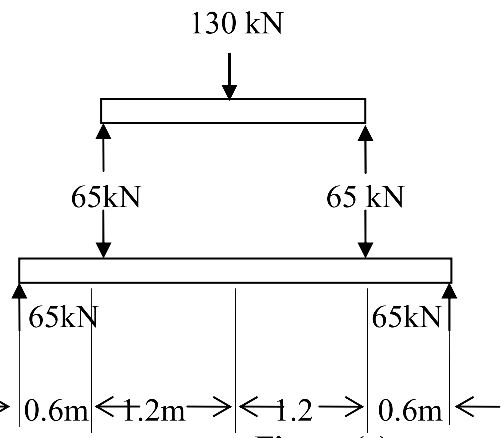


Figure (a)

Deflection of beam AB at point C

Now we consider simply supported beam AB with two point loads; 65 kN each acting at point C and D. The deflection y_2 at point C is determined by using superposition theorem.

<u>Deflection due to point load at point C</u>

a= 0.6 m ; b = 3.0 m ; L = 3.6 m ; x = a

Using relation

$$y' = \frac{P a^2 b^2}{3 E I L}$$

$$y' = \frac{65 \times 100 \times 0.6^2 \times 3^2}{3 \times 200 \times 10^9 \times 70.8 \times 10^{-6} \times 3.6} = 0.001377 \quad m$$

$$y' = 1.377 \quad mm$$

<u>Deflection at C due to point load at D</u>

a= 3.0 m; b = 0.6 m, L = 3.6 m; x< a

Using relation

$$y'' = \frac{Pb}{6EIL}\left[x^3 - \left(L^2 - b^2\right)x\right]$$

$$y'' = \frac{65 \times 1000 \times 0.6}{6 \times 200 \times 10^9 \times 70.8 \times 10^{-6} \times 3.6}\left[0.6^3 - \left(3.6^2 - 0.6^2\right) \times 0.6\right] = 0.000936 \quad m$$

$$\therefore y_2 = y' + y'' = 1.377 + 0.936$$

$y_2 = 2.313$

$y_D = y_1 + y_2 = 2.644 + 2.313$

$y_D = 4.96$ mm

6. Knowing that the couple shown in Figure (5) acts in vertical plane, determine the stress at point A and at point B.

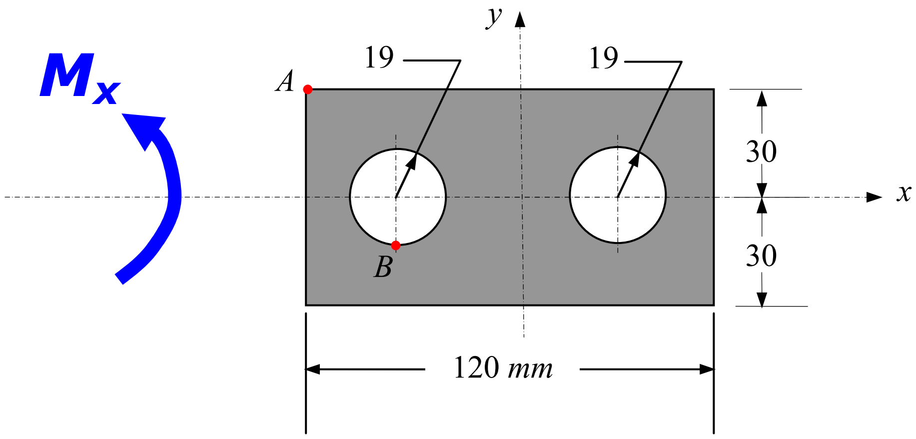


Figure (5)

Solution

Considering that the cross sectional area the centroidal moment of inertia of the section is;

$I = I_{(rectangle)} - 2\ I_{(circle)}$

$$I = \frac{bh^3}{12} - 2\left(\frac{\pi d^4}{64}\right)$$

$$I = \frac{120 \times 60^3}{12} - 2\left(\frac{\pi \times 38^4}{64}\right)$$

$I = 1955292.3 \quad mm^4$

Stress at point A

$$\sigma_A = \frac{Mc}{I}$$

M = 3 kN-m = $3x10^6$ N-mm

c = 30 mm

$$\therefore \sigma_A = \frac{3 \times 10^6 \times 30}{1955292.3}$$

$\sigma_A = -46.02 \quad \text{MPa} \quad \text{(compression)}$

Stress at point B

$$\sigma_B = \frac{Mc}{I}$$

c = 19 mm

$$\therefore \sigma_B = \frac{30 \times 10^6 \times 19}{1955292.3}$$

$\sigma_B = 29.15 \quad \text{MPa} \quad \text{(tension)}$