Arab Academy for Science, Technology & Maritime Transport.
College of Engineering & Technology,
Mechanical Engineering Department.

Stress analysis (ME 276)
Sheet No. 1.

(1) A metal wire is 2.5 mm diameter and 2 m long. A force of 120 N is applied to it and it stretches 0.3 mm. Assume the material is elastic. Determine the following:
(a) The stress in the wire,
(b) The strain in the wire.

(2) A steel tensile test specimen has a cross sectional area of 100 mm^2 and a gauge length of 50 mm, the gradient of the elastic section is 410 X 10^3 N/mm. Determine the modulus of elasticity.

(3) A steel column is 3 m long and 0.4 m diameter. It carries a load of 50 MN. Given that the modulus of elasticity is 200 GPa, calculate the compressive stress and strain and determine how much the column is compressed.

(4) Determine the average normal stress developed at points ***A***, ***B***, and ***C***. The diameter of each segment is indicated in Figure 1.

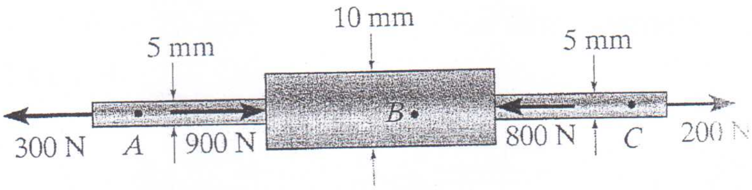


Figure 1.

(5) The bar shown in Figure 2 has a constant width of 35 mm and a thickness of 10 mm. Determine the maximum average normal stress in the bar when it is subjected to the loading shown.

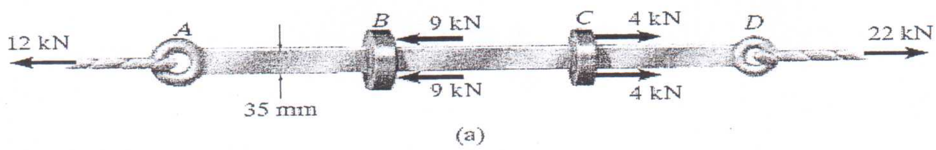


Figure 2.

(6) The steel bar shown in Figure 3 is made from two segments having cross-sectional areas of A_{AB} = 600 mm^2 and A_{BD} = 1200 mm^2. Determine the vertical displacement of end ***A*** and the displacement of ***B*** relative to ***C***. (***E*** = 200 GPa.)

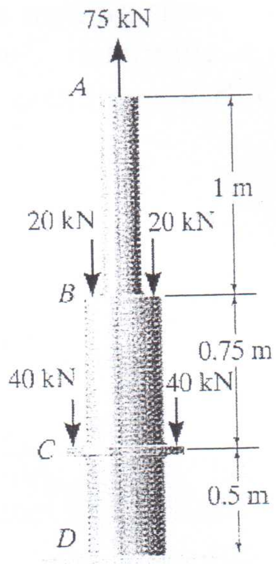


Figure 3.

(7) The 20 mm-diameter steel rod, shown in Figure 4, is subjected to the axial forces shown. Determine the displacement of end ***C*** with respect to the fixed support at ***A***. (***E*** = 200 GPa.)

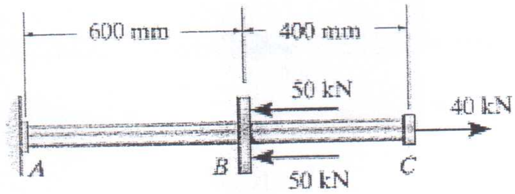


Figure 4.

(8) Segments ***AB*** and ***CD*** of the assembly shown in Figure 5 are solid circular rods and segment ***BC*** is a tube. If the assembly is made of aluminum of ***E*** = 70 GPa, determine the displacement of end ***D*** with respect to end ***A***.

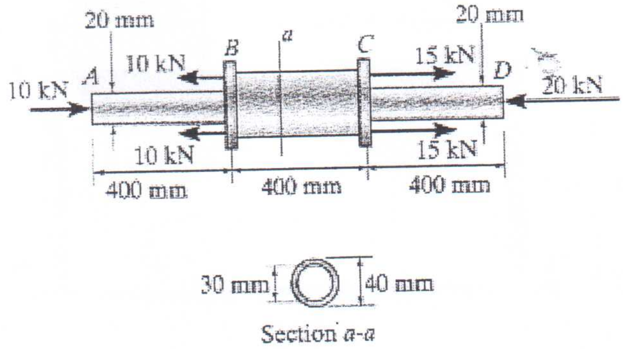


Figure 5.

(9) The steel rod shown in Figure 6 is subjected to the loading shown. If the cross-sectional area of the rod is 50 mm^2, determine the displacement of its end ***D***. Neglect the size of the couplings at ***B***, ***C***, and ***D***. (***E*** = 200 GPa.)

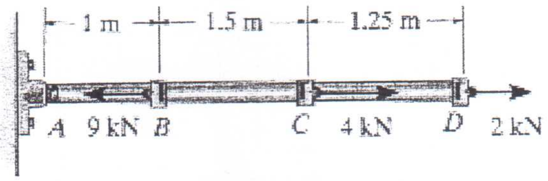


Figure 6.

(10) The assembly shown in Figure 7 consists of a steel rod ***CB*** and an aluminum rod ***BA***, each having a diameter of 12 mm. If the rod is subjected to the axial loadings at ***A*** and at the coupling ***B***, determine the displacement of the coupling ***B*** and the end ***A***. Neglect the size of the connections at ***B*** and C assuming that they are rigid. E_{st} = 200 GPa and E_{al} = 70 GPa.

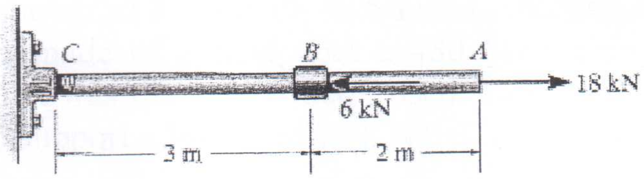
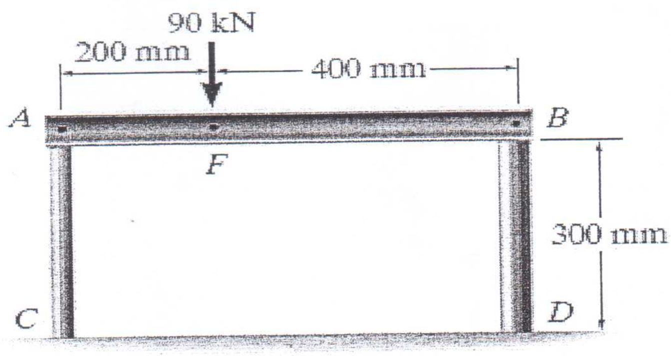


Figure 7.

(11) A rigid beam ***AB*** rests on the two short posts shown in Figure 8. ***AC*** is made of steel and has a diameter of 20 mm and ***BD*** is made of aluminum and has a diameter of 40 mm. Determine the displacement of point ***F*** on ***AB*** if a vertical load of 90 KN is applied over this point. Take E_{st} = 200 GPa and E_{al} = 70 GPa.



(a)
Figure 8.

(12) Members ***ABC*** and ***DEF***, shown in Figure 9, are joined with steel links (***E*** = 200 GPa). Each of the links is made of a pair of 25 X 35 mm plates. Determine the change in length of:
(a) Member ***BE***,
(b) Member ***CF***.

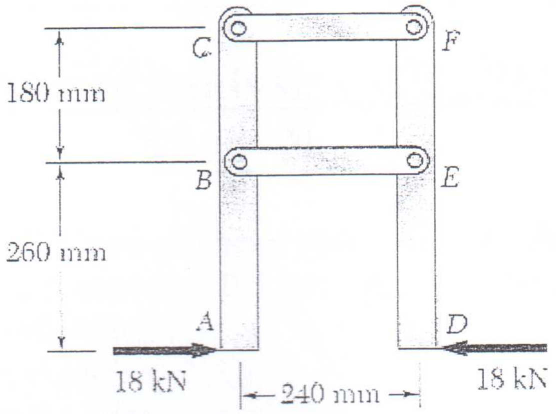


Figure 9.

(13) Link **BC**, shown in Figure 10, is 6 mm thick, has a width ***w*** = 25 mm, and is made of a steel with a 480 MPa ultimate strength in tension. What was the safety factor used if the structure shown was designed to support a load **P** of 16 KN?

(14) Link **BC**, shown in Figure 10, is 6 mm thick and is made of a steel with a 450 MPa ultimate strength in tension. What should be the width ***w*** if the structure is being designed to support a 20 KN load P with a factor of safety of 3?

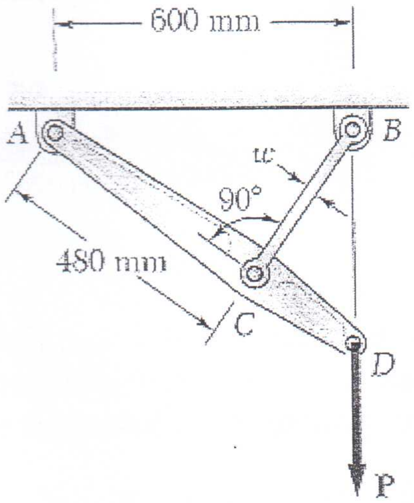


Figure 10.

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Stress analysis (ME 276)
Sheet No. 2.

(1) Calculate the force needed to shear a sheet of metal 5 mm thick and 0.8 m wide given that the ultimate shear stress is 50 MPa.

(2) Calculate the force needed to punch a hole 30 mm diameter in a sheet of metal 3 mm thick given that the ultimate shear stress is 60 MPa.

(3) Calculate the force needed to shear a pin 8 mm diameter given that the ultimate shear stress is 60 MPa.

(4) Two forces are applied to the bracket ***BCD*** as shown in Figure 1.

(*a*) Knowing that the control rod ***AB*** is to be made of steel having an ultimate normal stress of 600 MPa, determine the diameter of the rod for which the factor of safety with respect to failure will be 3.3.

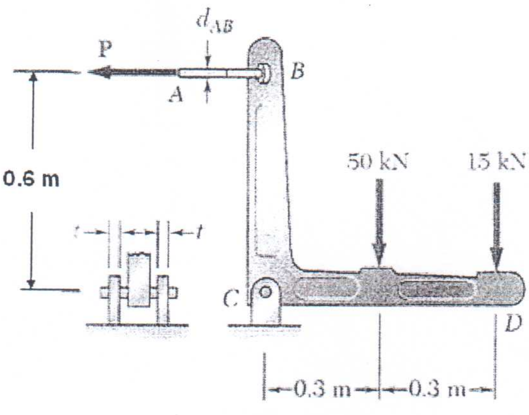
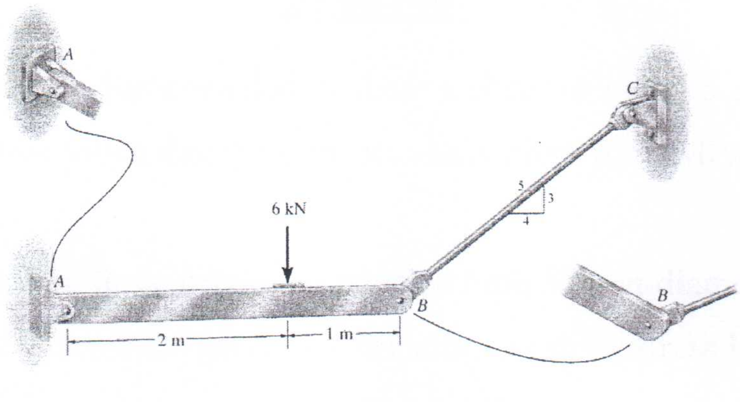


Figure 1.

(*b*) The pin at ***C*** is to be made of steel having an ultimate shearing stress of 350 MPa. Determine the diameter of the pin ***C*** for which the factor of safety with respect to shear will also be 3.3.

---

(5) The two members, shown in Figure 2, are pinned together at B. If the pins have an allowable shear stress of $\tau_{allow} = 90$ MPa, and allowable tensile stress of rod CB is $(\sigma_t)_{allow} = 115$ MPa. Determine to nearest mm the smallest diameter of pins A, B and C and the diameter of rod CB necessary to support the load.



(a)

Figure 2.

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Stress analysis (ME 276)
Sheet No. 3.

(1) A shaft 50 mm diameter and 0.7 m long is subjected to a torque of 1200 N.m. Calculate the shear stress and the angle of twist. Take G = 90 GPa.

(2) A hollow circular cross-sectional shaft 50 mm outer diameter and 30 mm inner diameter and 0.7 m long is subjected to a torque of 1200 N.m. Calculate the shear stress and the angle of twist. Take G = 90 Gpa.

(3) A shaft 40 mm diameter is made from steel and the maximum allowable shear stress for the material is 50 MPa. Calculate the maximum torque that can be safely transmitted by the shaft. Take G = 90 GPa.

(4) A shaft is made from tube 25 mm outer diameter and 20 mm inner diameter. The shear stress must not exceed 150 MPa. Calculate the maximum power that should be transmitted at 500 rev/min.

(5) A steel shaft 5 m long, having a diameter of 50 mm, is to transmit power at a rotational speed of 600 rev/min. If the maximum shear stress is limited to 60 MPa, determine the following:

(a) The maximum power that can be transmitted by the shaft.

(b) The corresponding angle of twist.

Assume the modulus of rigidity for steel is 80 GPa.

(6) A hollow steel shaft with a diameter ratio of 0.75 and a length of 4 m is required to transmit 1 MW at 120 rev/min. the maximum shear stress is not to exceed 70 MPa nor is the overall angle of twist to exceed 1.75. Determine the following:

(a) The necessary outside diameter of the shaft so that both the above limitations are satisfied.

(b) The actual maximum shear stress and the actual angle of twist.

Assume the modulus of rigidity for steel is 80 GPa.

(7) For the shaft/gear assembly shown in Figure 1, the shaft is driven by Gear at ***C***. Gears at ***B*** and ***D*** are driven by the shaft. It turns freely at ***A*** and ***E***. T_2 = 450 N.m, T_1 = 275 N.m, T_3 = 175 N.m, ***d*** = 30 mm, L_{BC} = 500 mm, L_{CD} = 400 mm, and ***G*** = 80 GPa. Determine the maximum shear stress and the angle of twist between gears ***B*** and ***D***.

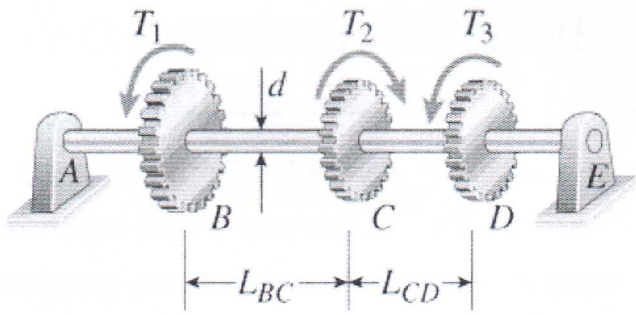

Figure 1.

(8) Solid steel shaft in torsion shown in Figure 2. The motor transmits ***50 kW*** to the shaft ***ABC*** of ***50 mm*** diameter at ***10Hz***. The gears at ***B*** and ***C*** extract ***35 kW*** and ***15 kW*** respectively. Calculate the maximum shear stress in the shaft and the angle of twist (□***AC***) between the motor and the gear ***C***. Use ***G*** = 80 GPa.

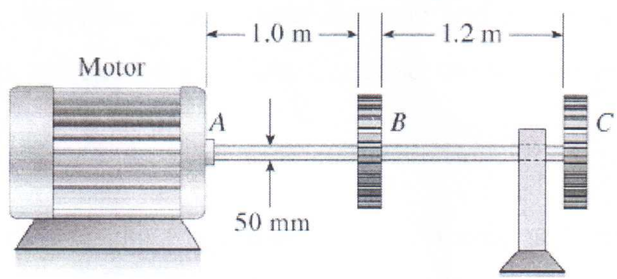

Figure 2.

(9) The horizontal shaft ***AD*** is attached to a fixed base at ***D*** and is subjected to the torques as shown in Figure 3. A 44 mm diameter hole has been drilled into portion ***CD*** of the shaft. Knowing that the entire shaft is made of steel for which ***G*** = 77 GPa, determine the angle of twist at end ***A***.

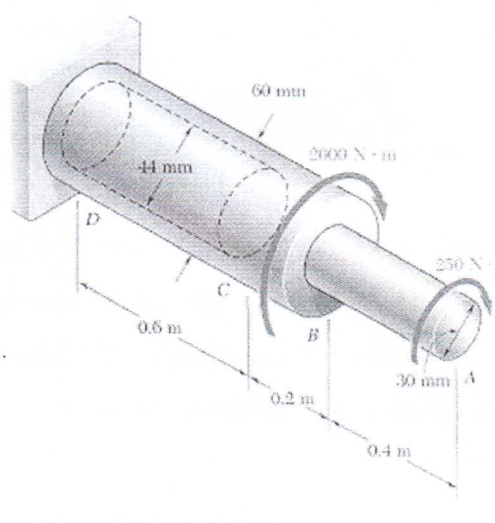

Figure 3.

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Stress analysis (ME 276)
Sheet No. 4.

(1) Determine the state of stress at point ***A*** on the cross section of the pipe at section ***a-a*** shown in Figure 1.

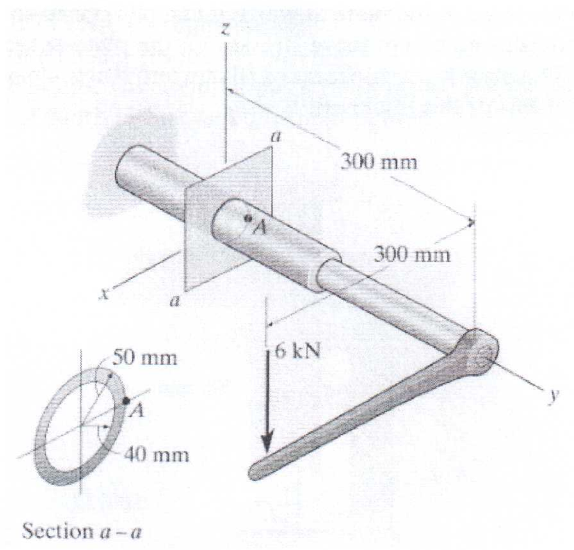

Figure 1.

(2) Determine the state of stress at point ***A*** on the cross section of the pipe assembly at section ***a-a*** shown in Figure 2.

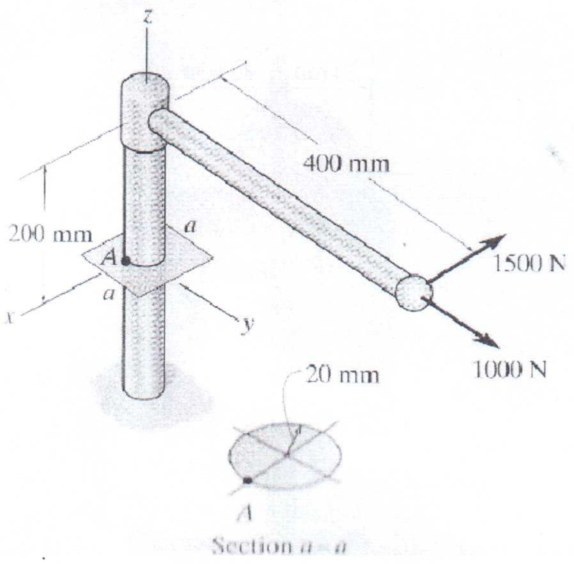

Figure 2.

(3) The joint, shown in Figure 3, is subjected to forces ***P*** = 1 KN and ***F*** = 0.75 KN. Determine the state of stress at points ***A*** and ***B***. The member has a rectangular cross-sectional area of width 18 mm and thickness 12 mm.

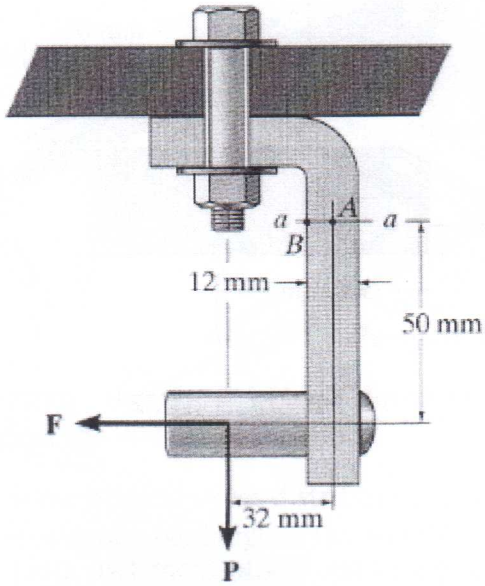

Figure 3.

(4) The bar, shown in Figure 4, has a diameter of 80 mm. Determine the stress components that act at points ***A*** and ***B***.

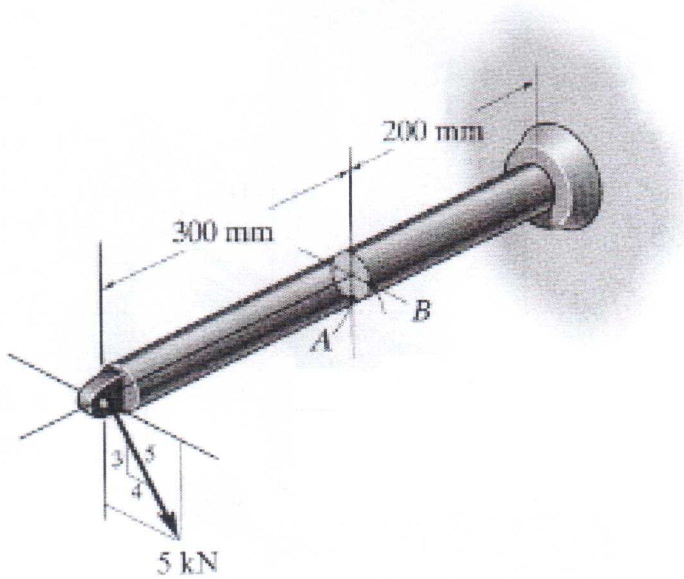

Figure 4.

(5) The bar shown in Figure 5 has a diameter of 40 mm. If it is subjected to the two force components at its end as shown, determine the state of stress at points ***A*** and ***B***.

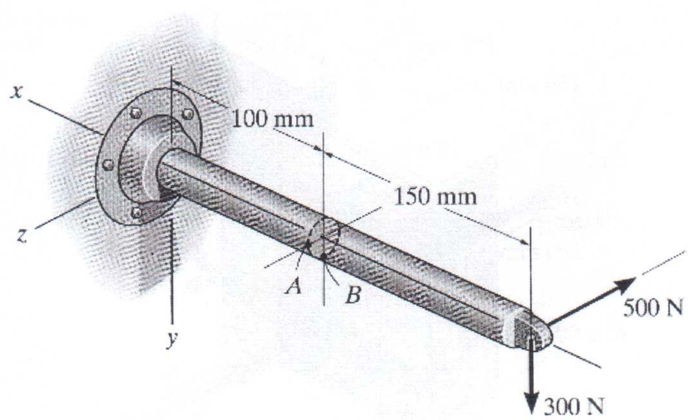

Figure 5.

(6) The 50 mm diameter rod, shown in Figure 6, is subjected to the loads shown. Determine the state of stress at points ***A*** and ***B***.

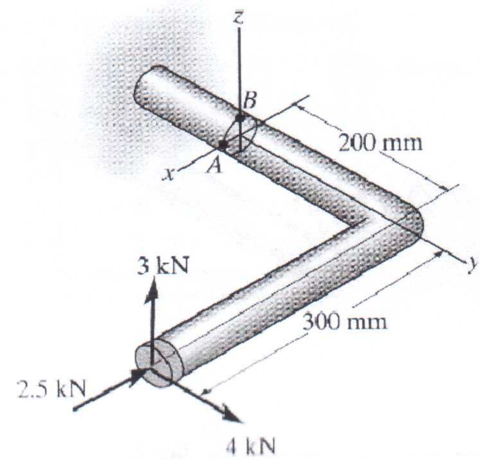

Figure 6.

(7) The uniform sign, shown in Figure 7, has a weight of 7.5 KN and is supported by the pipe ***AB***, which has an inner radius of 68 mm and outer radius of 75 mm. If the face of the sign is subjected to a uniform wind pressure of ***P*** = 8 KN/m2, determine the state of stress at points ***C, D, E*** and ***F***. Neglect the thickness of the sign and assume that it is supported along the outside edge of the pipe.

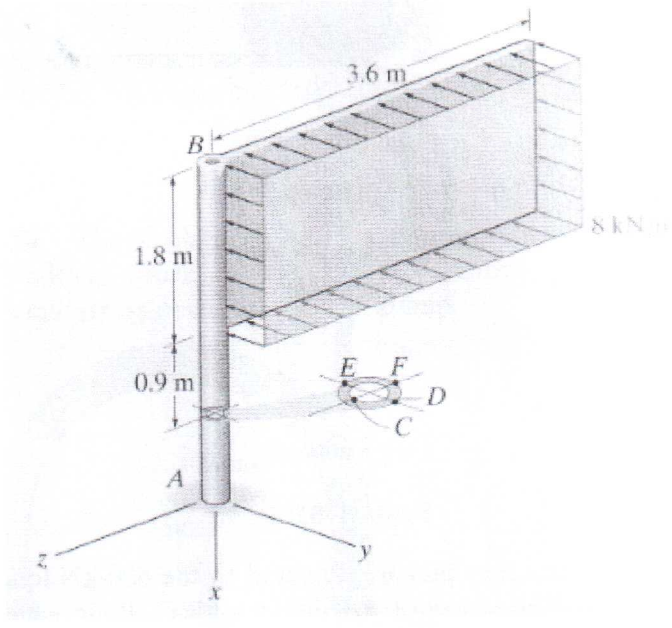

Figure 7.

(8) Determine the state of stress at points ***A*** and ***B*** on the cross section of the pipe at section ***a-a*** as shown in Figure 8.

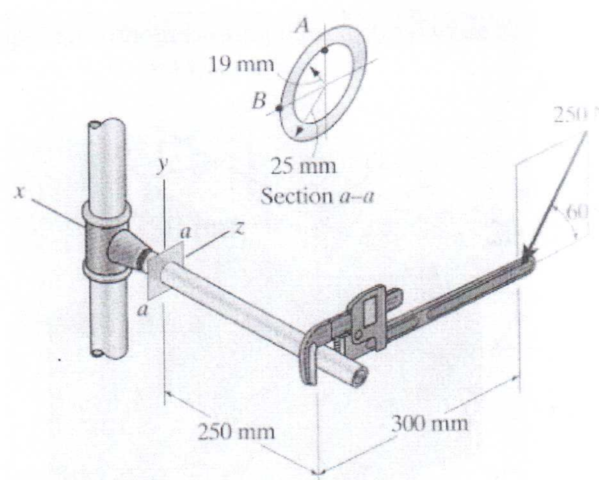

Figure 8.

(9) The bent rod, shown in Figure 9, has a diameter of 20 mm and is subjected to the force of 400 N. Determine the principal stresses and the maximum shear stress that is developed at point A.

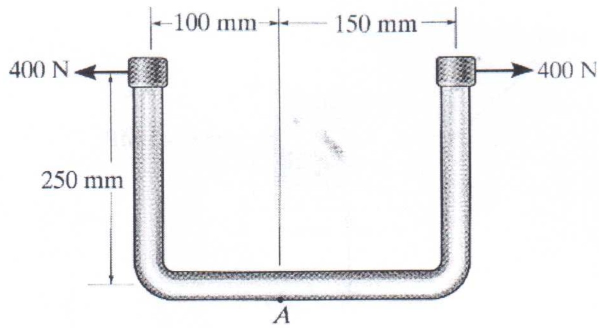

Figure 9.

(10) The bracket, shown in Figure 10, is subjected to the force of 15 KN. Determine the principal stress and maximum shear stress at points A and B on the cross section at section a-a.

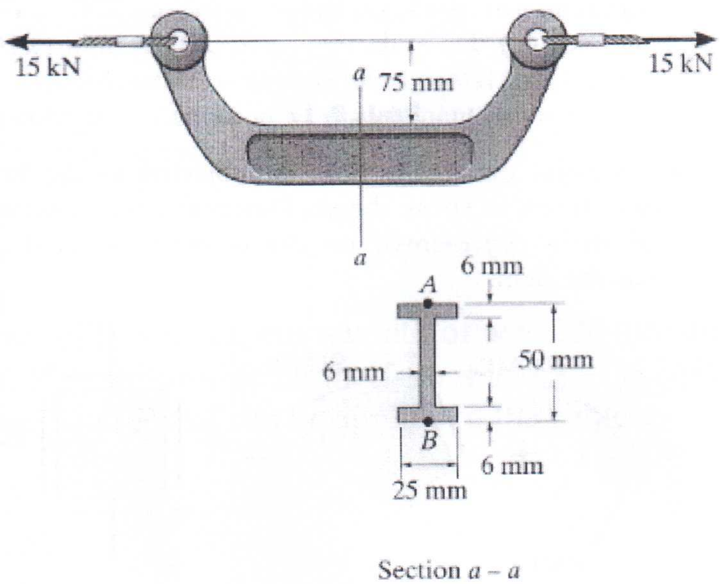

Figure 10.

(11) For the cantilever shown in Figure 11, determine the principal stress developed at point A on the cross section at section a-a.

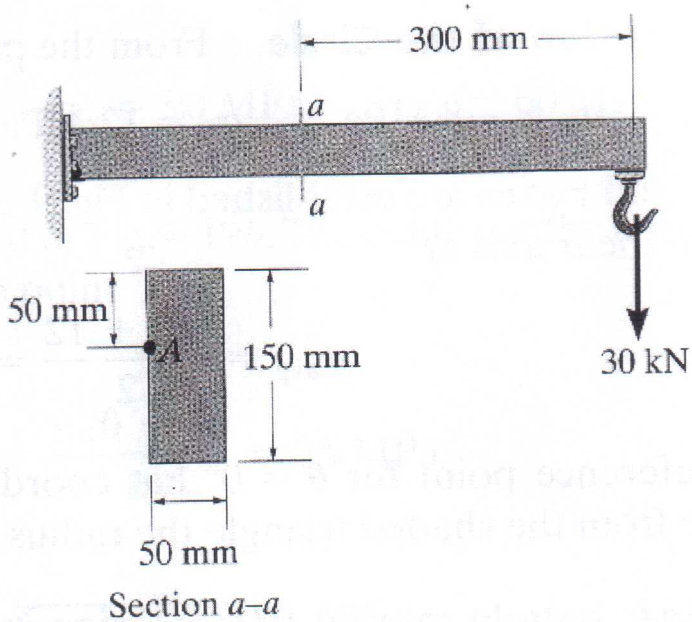

Figure 11.

(12) The steel pipe, shown in Figure 12, has an inner diameter of 68 mm and an outer diameter of 75 mm. If it is fixed at ***C*** and subjected to the horizontal 100 N force acting on the handle of the pipe wrench at its end, determine the principal stresses in the pipe at points ***A*** and ***B***, which are located on the surface of the pipe.

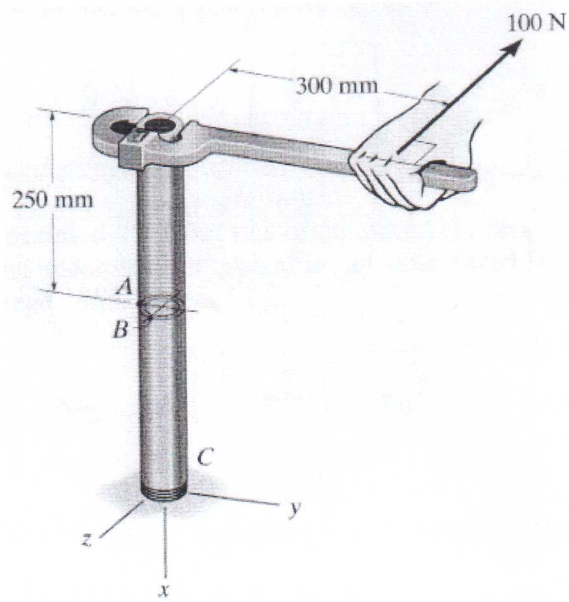

Figure 12.

(13) The offset link, shown in Figure 13, has a width of w = 200 mm and a thickness of 40 mm. If the allowable normal stress is σ_{all} = 75 MPa, determine the maximum load ***P*** that can be applied to the cables.

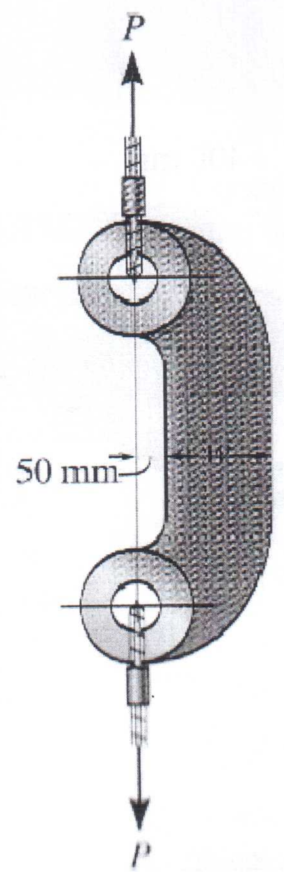

Figure 13.

(14) The wide-flange cantilever shown in Figure 14 is subjected to loading shown. Determine the principal stress at points *A* and *B*. these points are located at the top and bottom of the web, respectively.

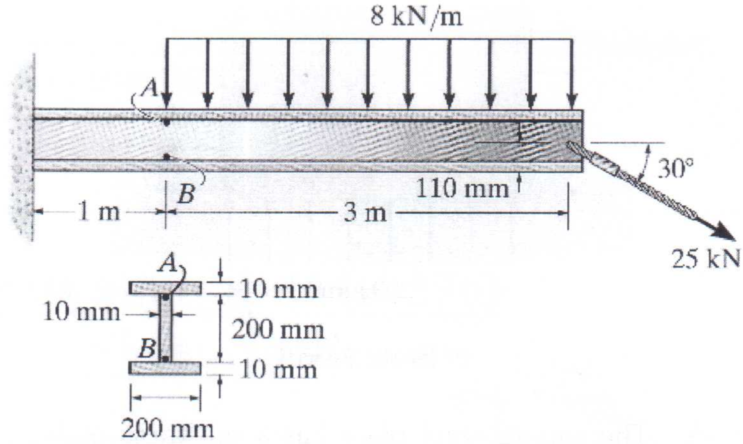

Figure 14.

Although it is not very accurate, use the shear formula to determine the shear stress.

(15) The propeller shaft of the tugboat, shown in Figure 15, is subjected to the compressive force and torque shown. If the shaft has an inner diameter of 100 mm and an outer diameter of 150 mm, determine the principal stress at a point *A* located on the outer surface.

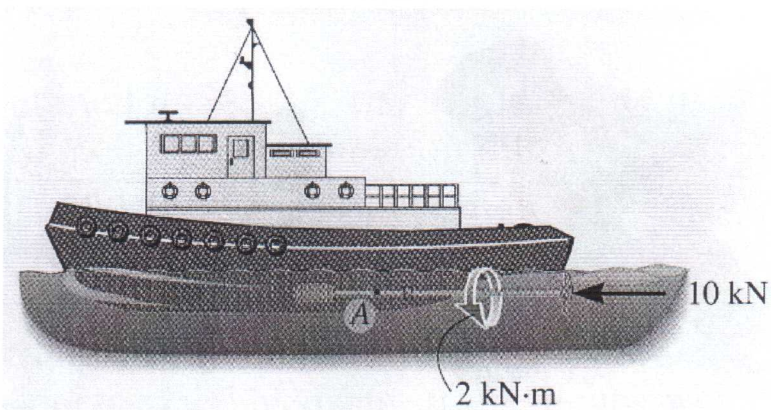

Figure 15.

(16) Determine the state of stress at point *A* on the cross section of the shaft at section *a-a* shown in Figure 16.

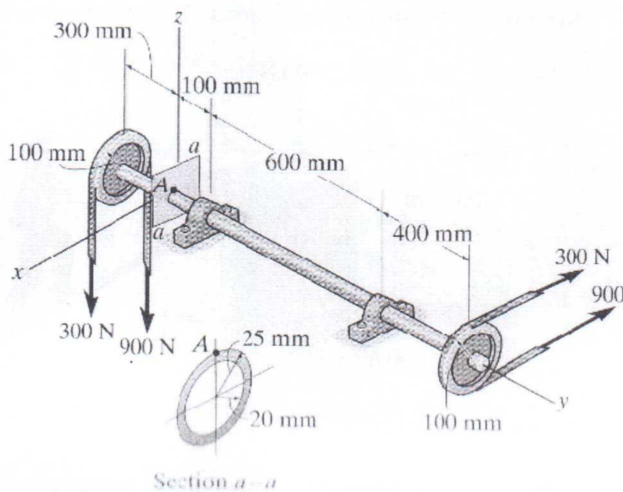

Figure 16.

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Stress analysis (ME 276)
Sheet No. 5.

For each of the loaded beams/cantilevers that shown in Figures 1 to 13 draw ***to suitable scale*** the normal forces diagram, the shear forces diagram and the bending moments diagram. Illustrate, on each diagram, the values at supports, points of loading and points of load changing.

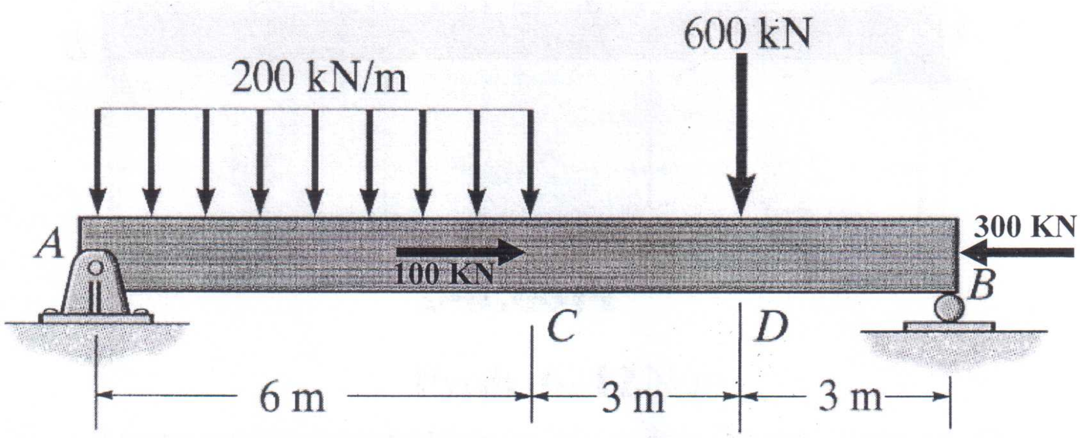

Figure 1.

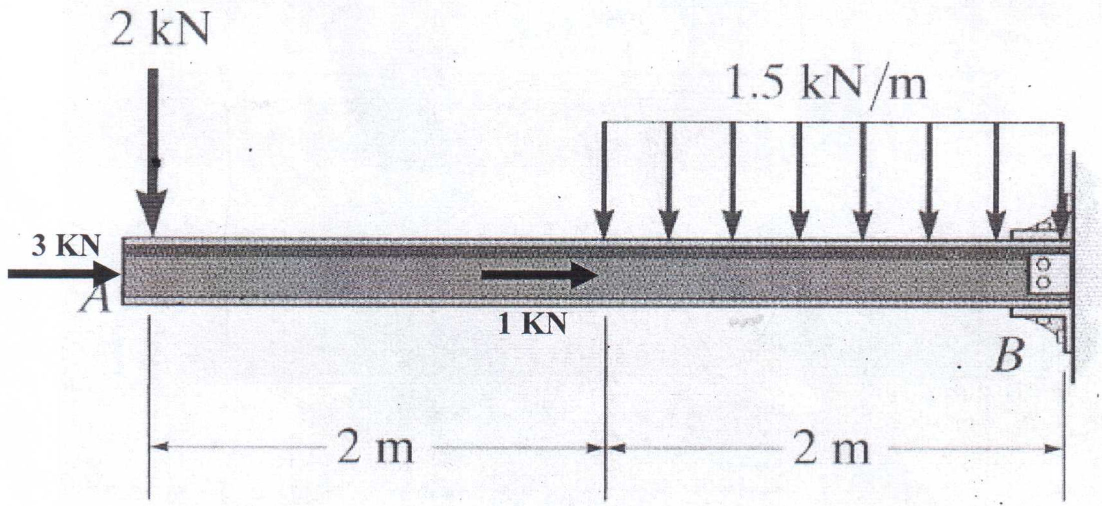

Figure 2.

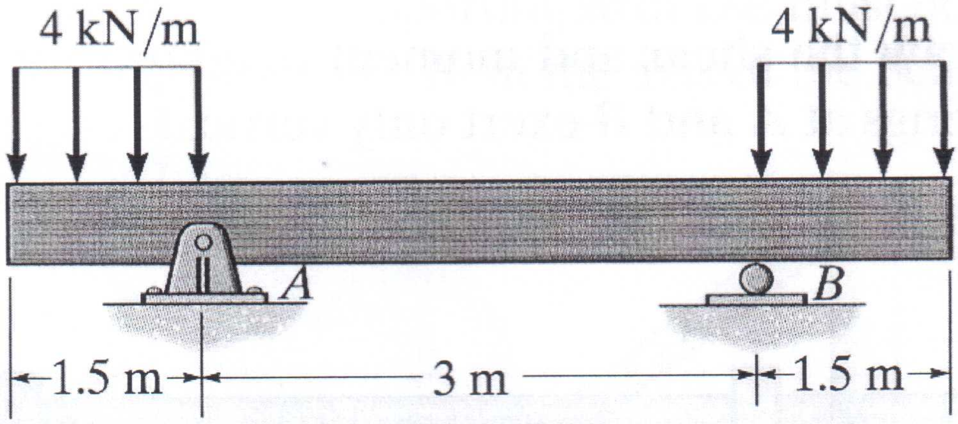

Figure 3.

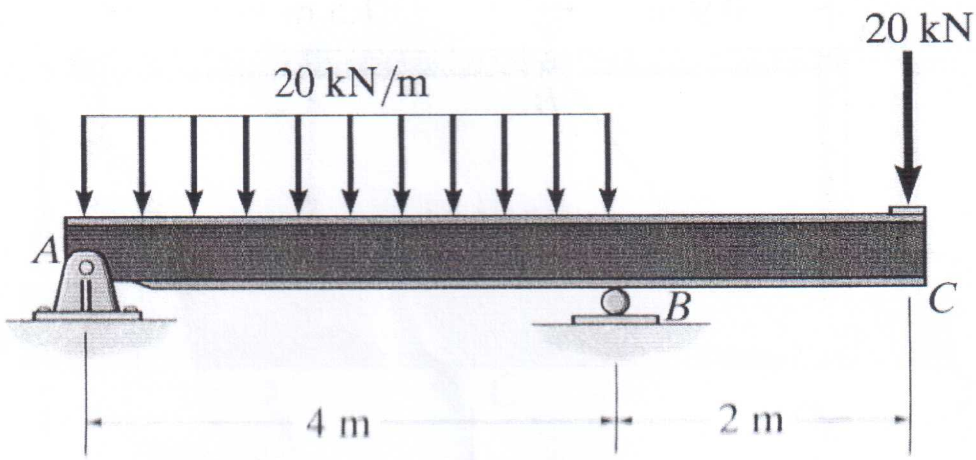

Figure 4.

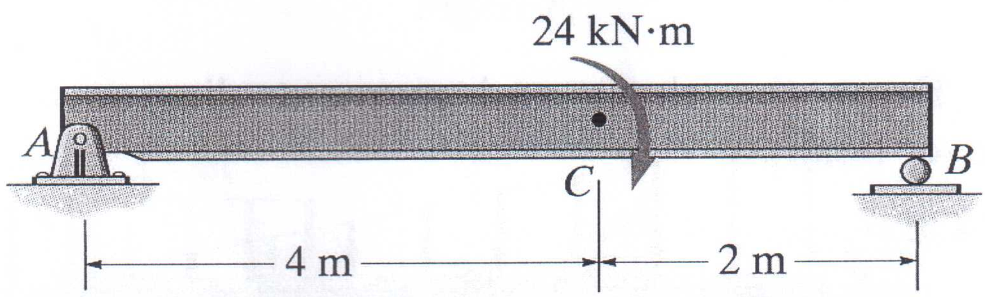

Figure 5.

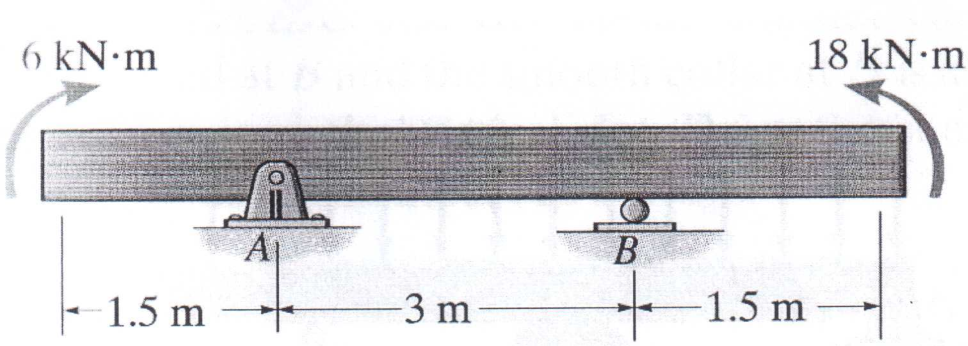

Figure 6.

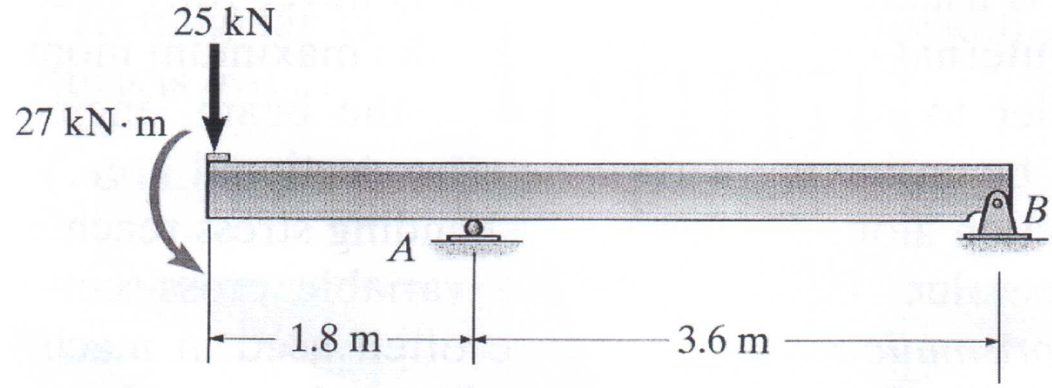

Figure 7.

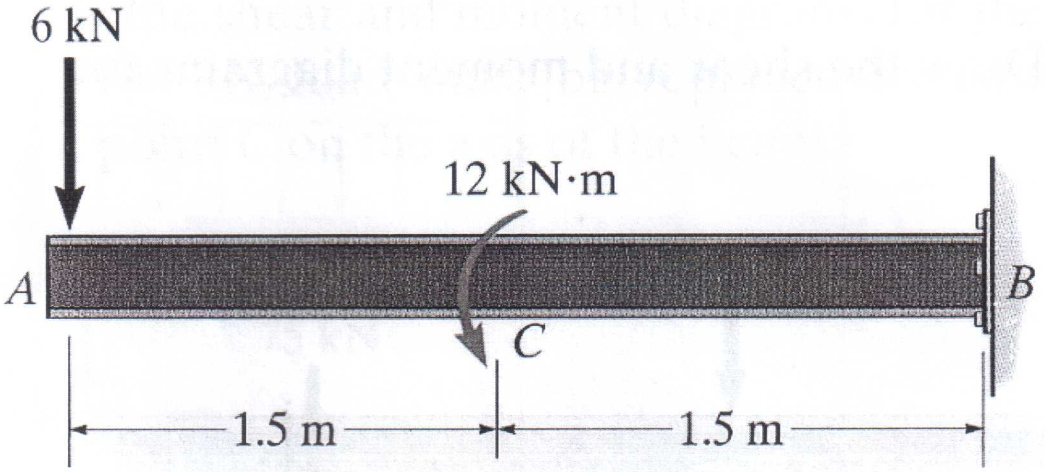

Figure 8.

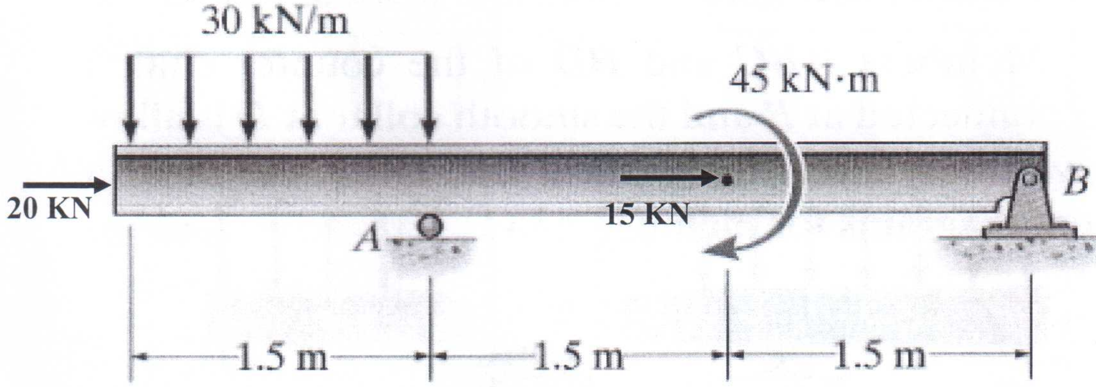

Figure 9.

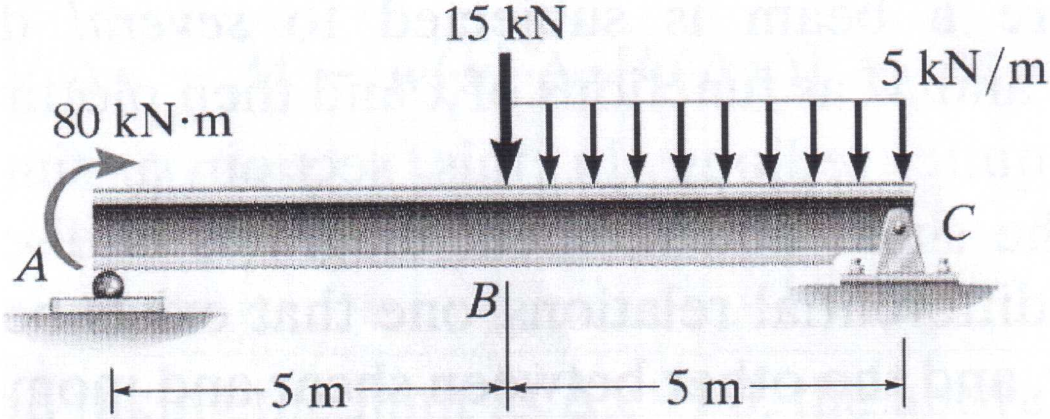

Figure 10.

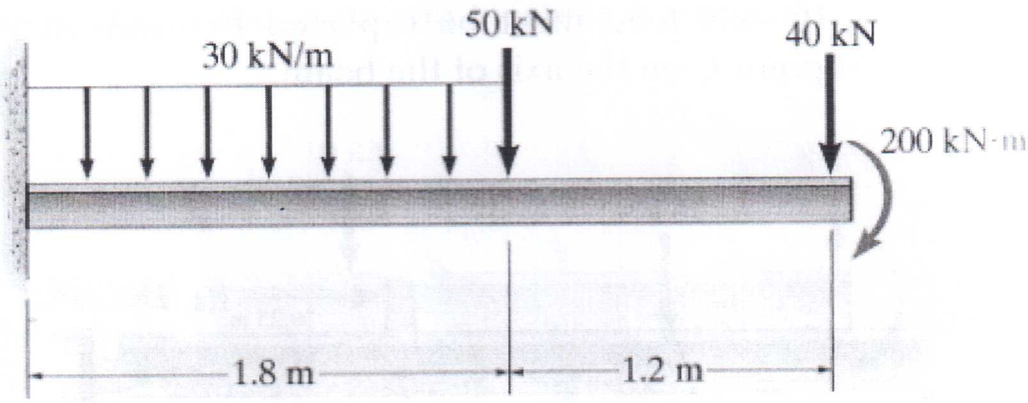

Figure 11.

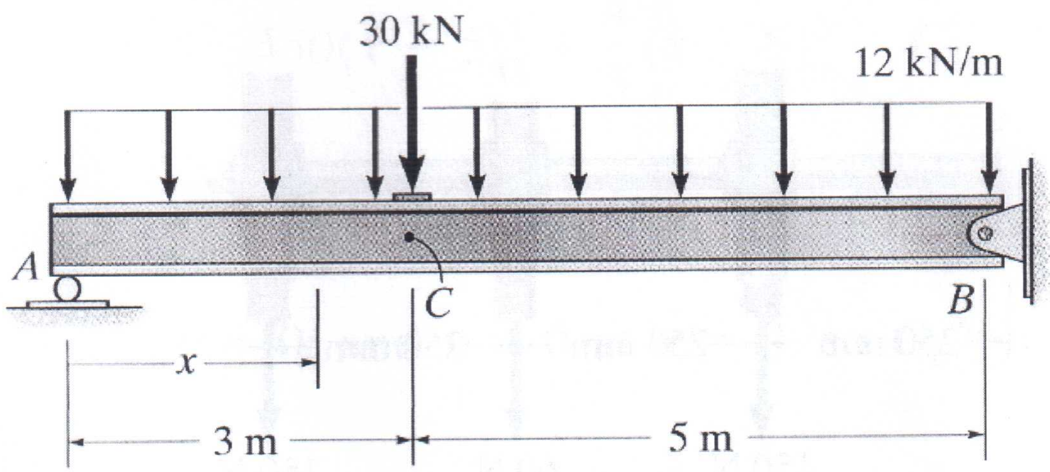

Figure 12.

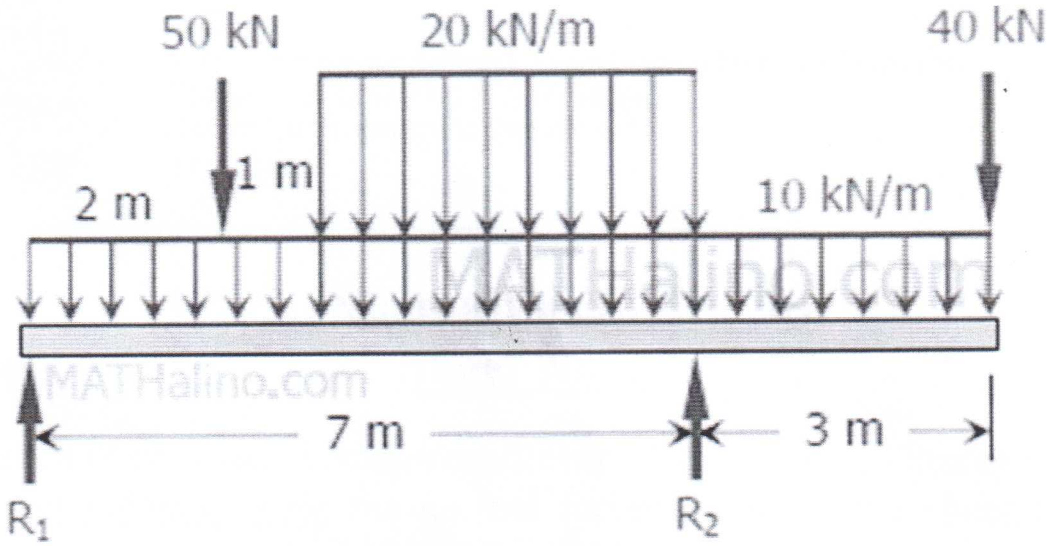
50 kN
20 kN/m
40 kN
1 m
2 m
10 kN/m
MATHalino.com
MATHalino.com
7 m
3 m
R1
R2

Figure 13.

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Stress analysis (ME 276)
Sheet No. 6.

(1) The loaded beam shown in **Figure 1** is made of southern pine for which E = 13 GPa. Determine the slope of deflection at points A, B and C and the deflection/displacement at point A.

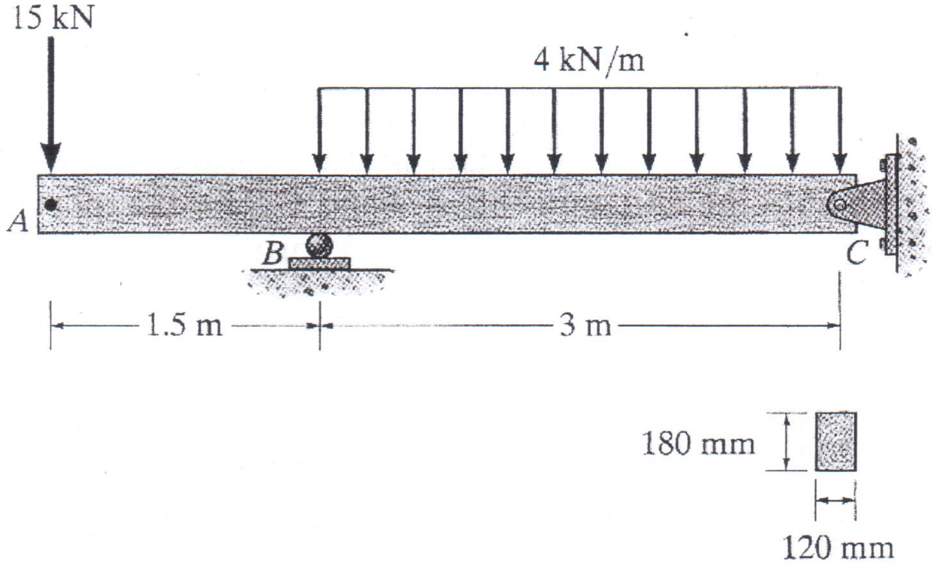

Figure1.

(2) The loaded beam shown in **Figure 2** is made of A-36 steel for which E = 200 GPa and $I = 70 \times 10^6$ mm^4. Determine the displacement at C and the slope at A and B.

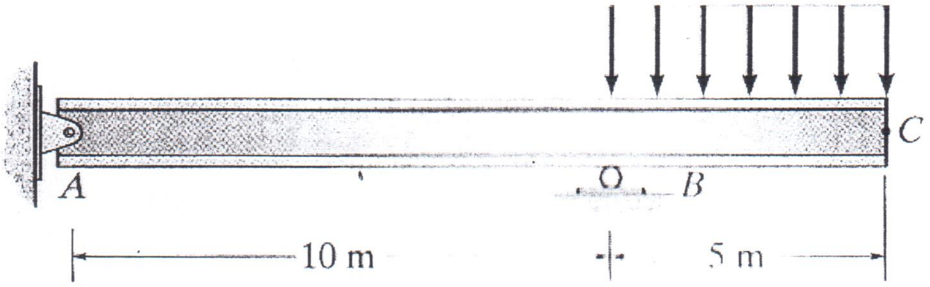

Figure 2.

(3) For the loaded beam shown in **Figure 3** derive the equation of the elastic curve. ***EI*** is constant. Determine, in terms of ***EI***, the displacement at the both ends of the beam and the maximum displacement.

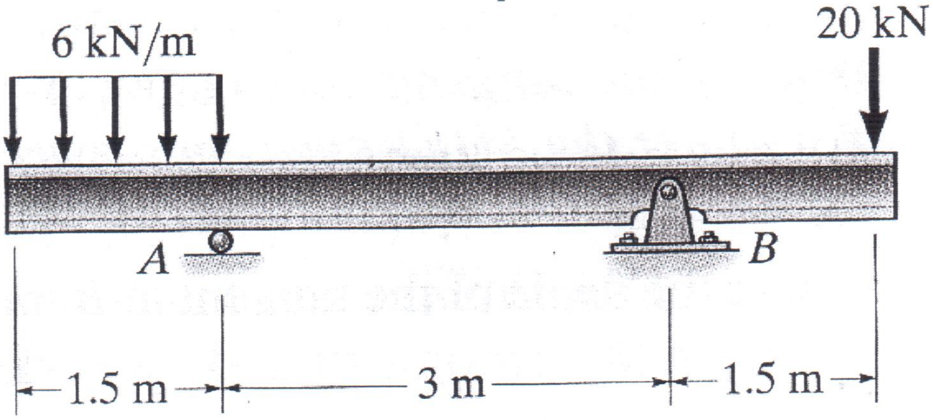

Figure 3.

(4) Derive the equations of the slope and elastic curve for the loaded beam shown in **Figure 4**. ***EI*** is constant. Determine the following in terms of ***EI***:

a. The slope of deflection at ***A*** and ***B***,

b. The deflection/displacement at the right end of the beam and at the midpoint between ***A*** and ***B***.

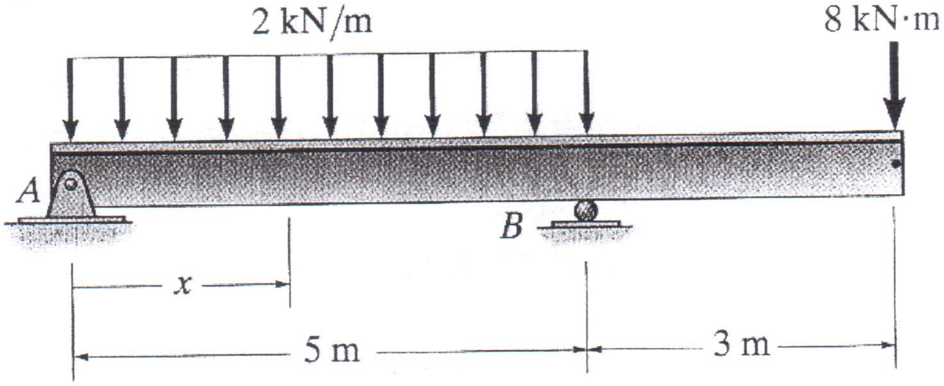

Figure 4.

(5) Determine the equation of the elastic curve of the simply supported beam which is illustrated in **Figure 5** and then find the maximum deflection. The beam is made of wood having a modulus of elasticity ***E*** = 10 GPa.

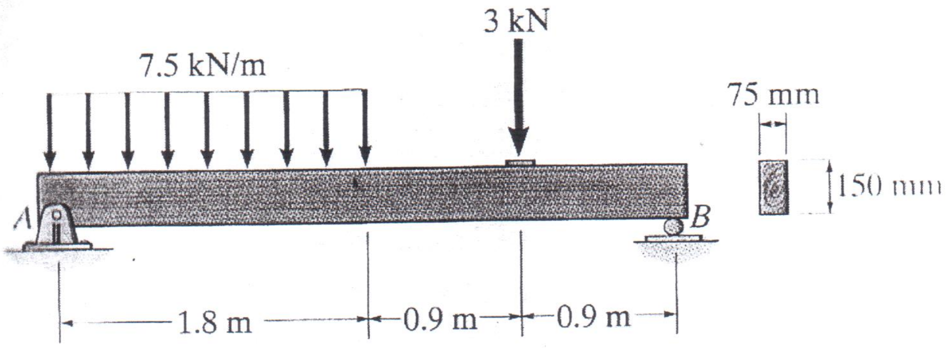

Figure 5.

(6) For the loaded wooden beam shown in **Figure 6** determine the equation of the elastic curve. If the modulus of elasticity $E_w = 12$ GPa, determine the deflection and the slope at end ***B***.

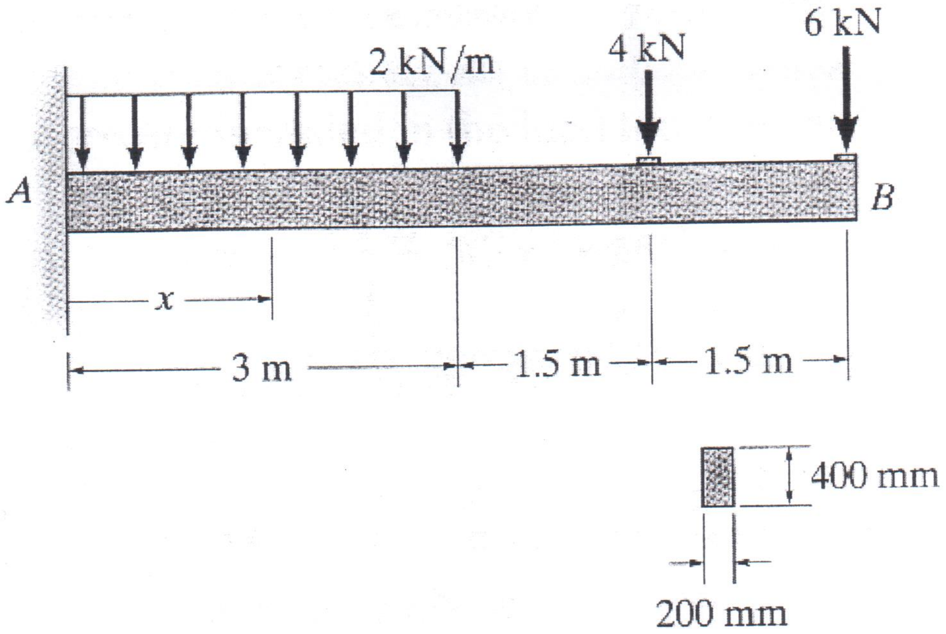

Figure 6.

(7) For the beam shown in **Figure 7** determine the slopes at ***A*** and ***B*** and the displacement at ***C***. ***EI*** is constant.

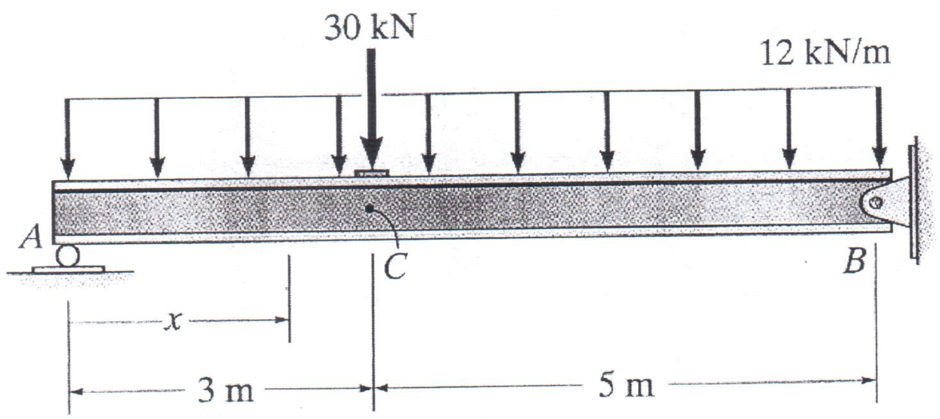

Figure 7.

(8) For the beam shown in **Figure 8** determine the displacement at $X = 7$ m and the slope at A. EI is constant.

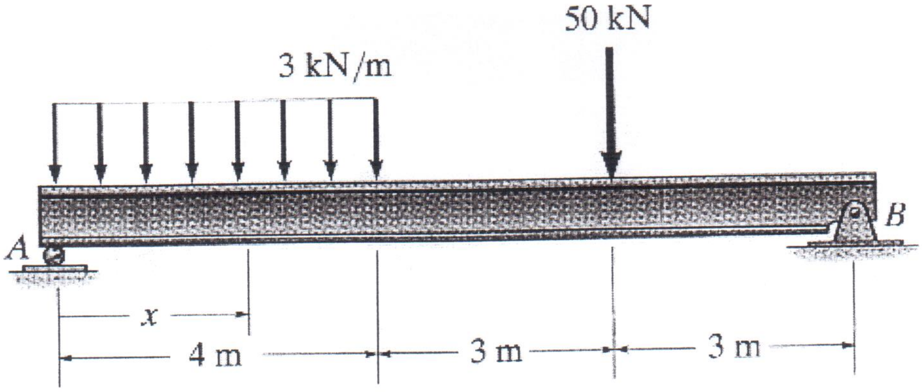

Figure 8.

(9) For the beam shown in **Figure 9** determine the displacement at $X = 1.5$ m and the slopes at A and B. EI is constant.

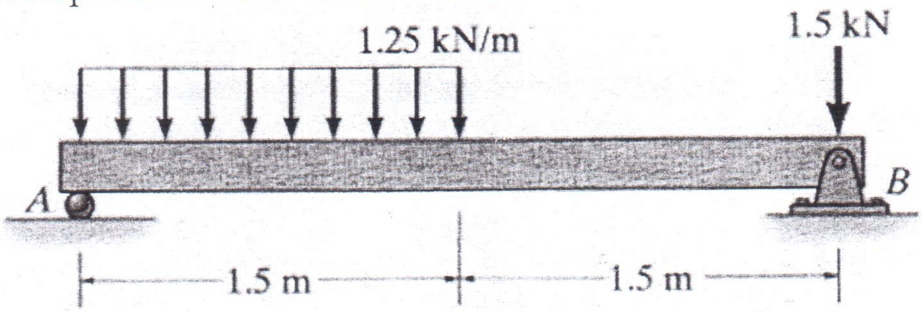

Figure 9

(10) Derive the equations of the slope and elastic curve for the loaded beam shown in **Figure 10**. EI is constant. Determine the following in terms of EI:

a. The slope of deflection at A and B,

b. The deflection/displacement at the lift end of the beam and at the midpoint between A and B.

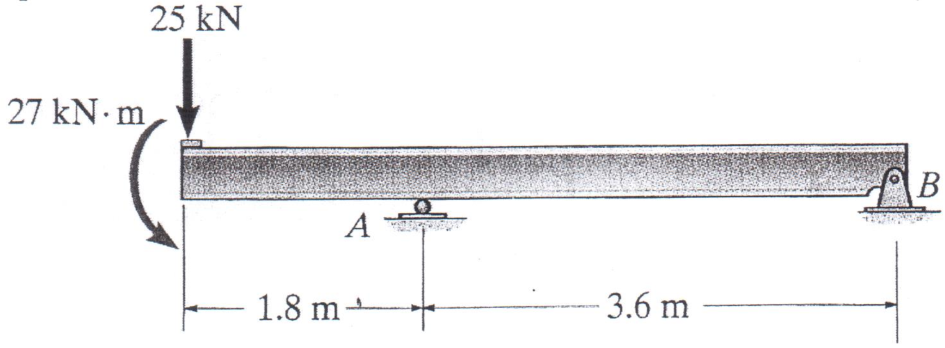

Figure 10.

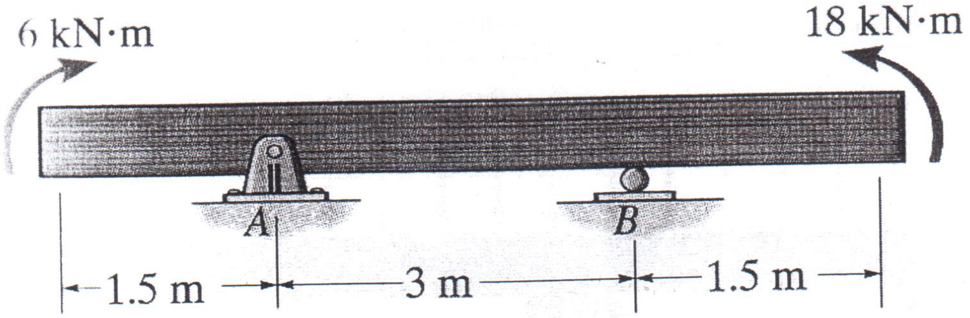

Figure 14.

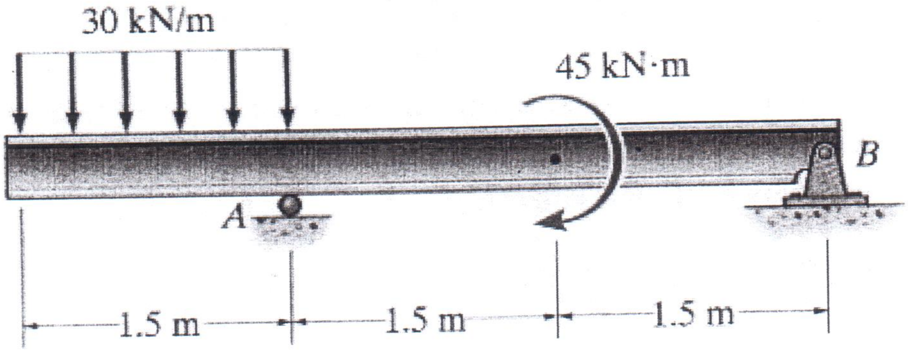

Figure 15.

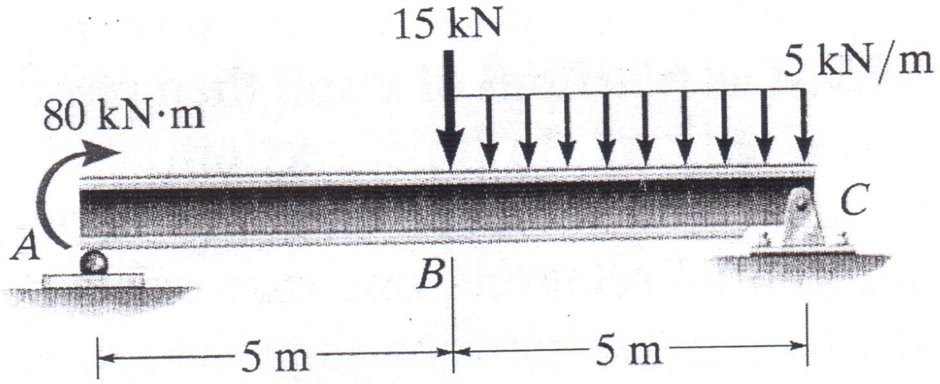

Figure 16.

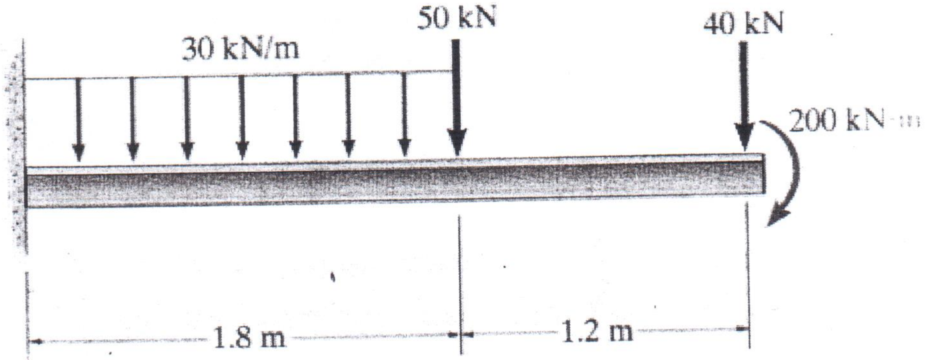

Figure 17.

(11) For the beams and cantilevers shown in **Figures 11 to 17** Derive the equations of the slope and elastic curve and hence determine, in terms of ***EI***, the maximum displacement.

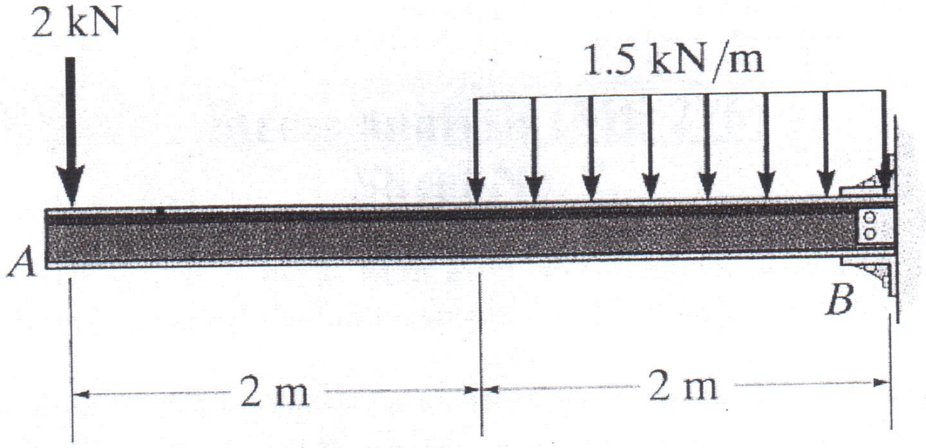

Figure 11.

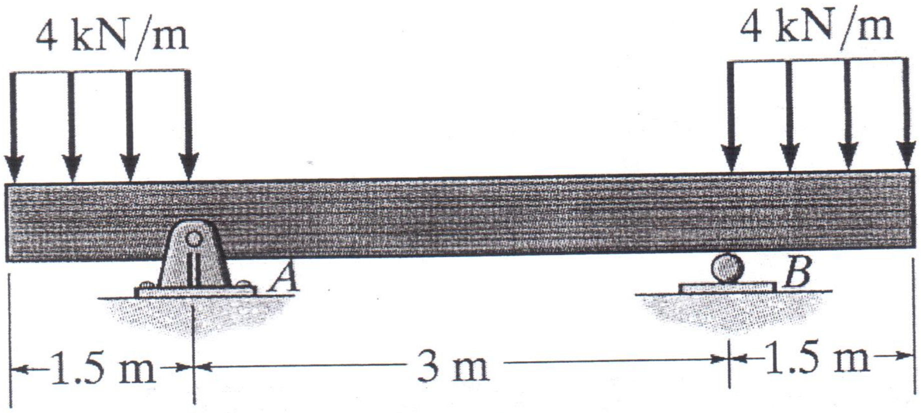

Figure 12.

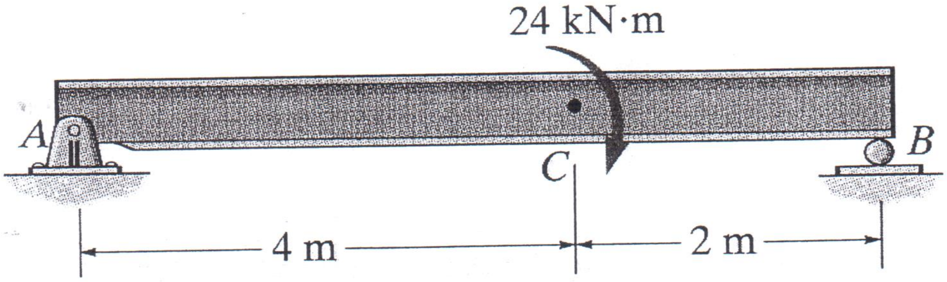

Figure 13.

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Stress analysis (ME 276)
Sheet No. 7.

(1) A 1.25 m long rod is made from a 25 mm diameter steel rod. Determine the critical buckling load if the both ends are fixed supported. E = 200 GPa.

(2) A 3.6 m long wooden rectangular column has the dimensions shown in **Figure 1**. Determine the critical load if the both ends are assumed to be fixed supported. E = 12 GPa.

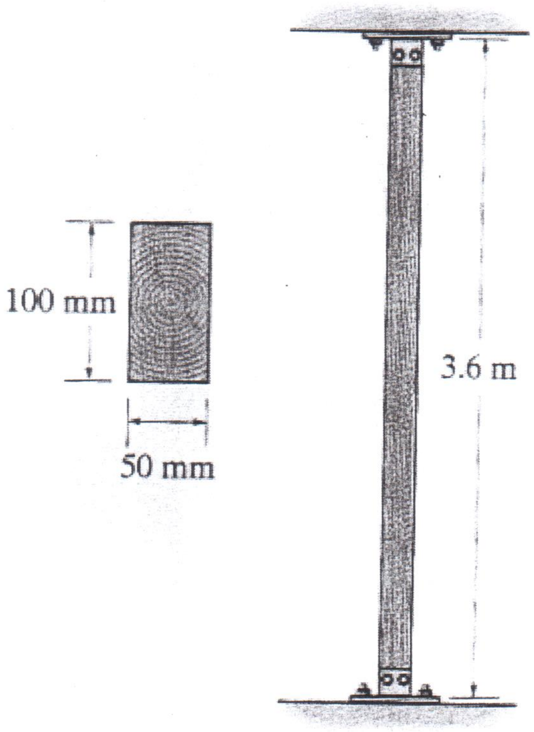

Figure 1.

(3) A **W360 X 57** column is made of **A-36** steel (E = 200 GPa, $I_X = 160\text{x}10^6$ mm^4 and $I_Y = 11.1\text{x}10^6$ mm^4). The column is fixed supported at its base and free at the top. If the column is subjected to an axial load P = 75 KN, determine the factor of safety with respect to buckling.

(4) The **W360 X 57** column, shown in **Figure 2**, is made of **A-36** steel ($E = 200$ GPa, $I_X = 160\text{x}10^6$ mm^4 and $I_Y = 11.1\text{x}10^6$ mm^4). Determine the critical load, P_{cr}, if the lower end of the column is fixed supported and the upper end is free to move about the strong axis (X-axis) and is pinned about the weak axis (Y-axis).

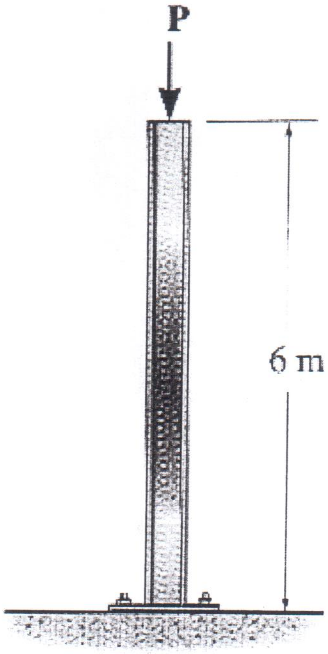

Figure 2.

(5) A column is made of **A-36** steel ($E = 200$ GPa, $I_X = 160\text{x}10^6$ mm^4 and $I_Y = 11.1\text{x}10^6$ mm^4) has a length of 6 m and is pinned at both ends. If the cross-sectional area has the dimensions shown in **Figure 3**, determine the critical load.

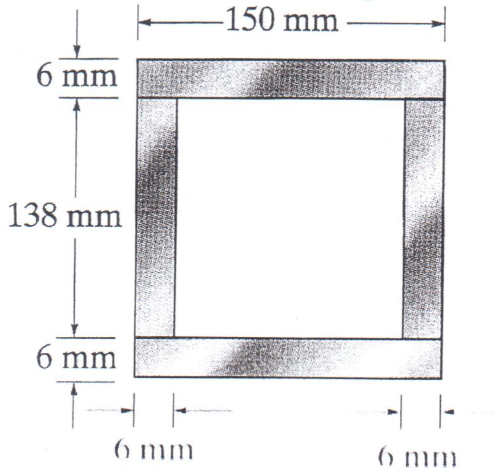

Figure 3.

(6) A column is made of **2014-T6** aluminum ($E = 73$ GPa) has a length of 9 m and is fixed at its bottom and pinned at its top. If the cross-sectional area has the dimensions shown in **Figure 3**, determine the critical load.

(7) An **A-36** steel column (***E*** = 200 GPa) has a length of 4 m and is pinned at both ends. If the cross-sectional area has the dimensions shown in **Figure 4**, determine the critical load.

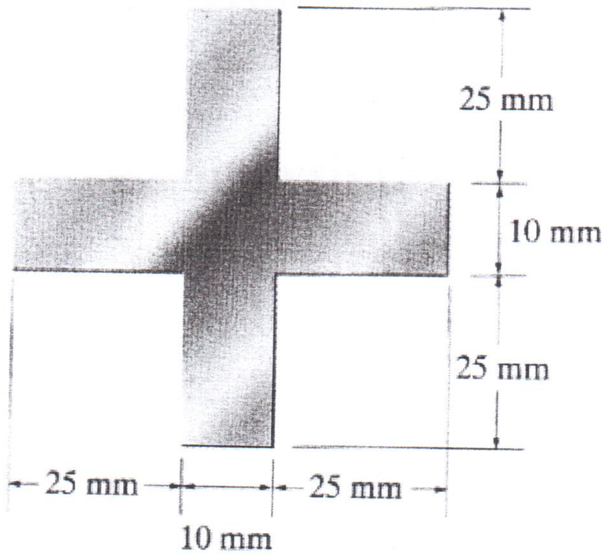

Figure 4.

(8) Solve problem (7) if the column is fixed supported at its bottom and pinned at its top.

(9) An **A-36** steel column (***E*** = 200 GPa) has a length of 5 m and is fixed supported at both ends. If the cross-sectional area has the dimensions shown in **Figure 5**, determine the critical load.

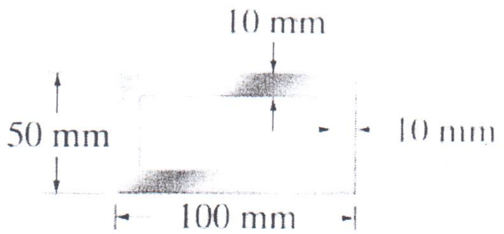

Figure 5.

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Stress analysis (ME 276)
Sheet No. 8.

(1) A cylindrical pressure vessel has an inner diameter of 1.2 m and a thickness of 12 mm. Determine the maximum internal pressure it can sustain so that neither its circumferential nor its longitudinal stress component exceeds 140 MPa. Under the same conditions, what is the maximum internal pressure that a similar-diameter spherical vessel can sustain?

(2) A spherical gas tank has an inner radius of r = 1.5 m. If it is subjected to an internal pressure of P = 300 KPa, determine its required thickness if the maximum normal stress is not to exceed 12 MPa.

(3) A pressurized spherical tank is to be made of 12-mm-thick steel. If it is subjected to an internal pressure of P = 1.4 MPa, determine its outer radius if the maximum normal stress is not to exceed 105 MPa.