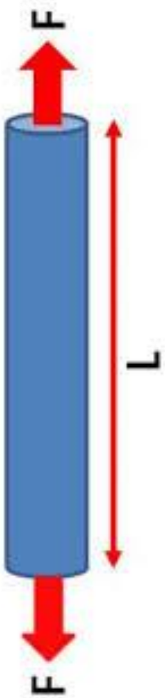
AXIAL LOAD



AXIAL LOAD

CHAPTER OBJECTIVES

The string of drill pipe stacked on this oil rig will be subjected to extremely large axial deformations when it is placed in the hole.

- In Chapter 1 , we developed the method for finding the normal stress in axially loaded members.
- In this chapter we will discuss how to determine the deformation of these members.
- Develop a method for finding the support reactions when these reactions cannot be determined strictly from the equations of equilibrium.
- An analysis of the effects of thermal stress, stress concentrations, inelastic deformations, and residual stress will also be discussed.

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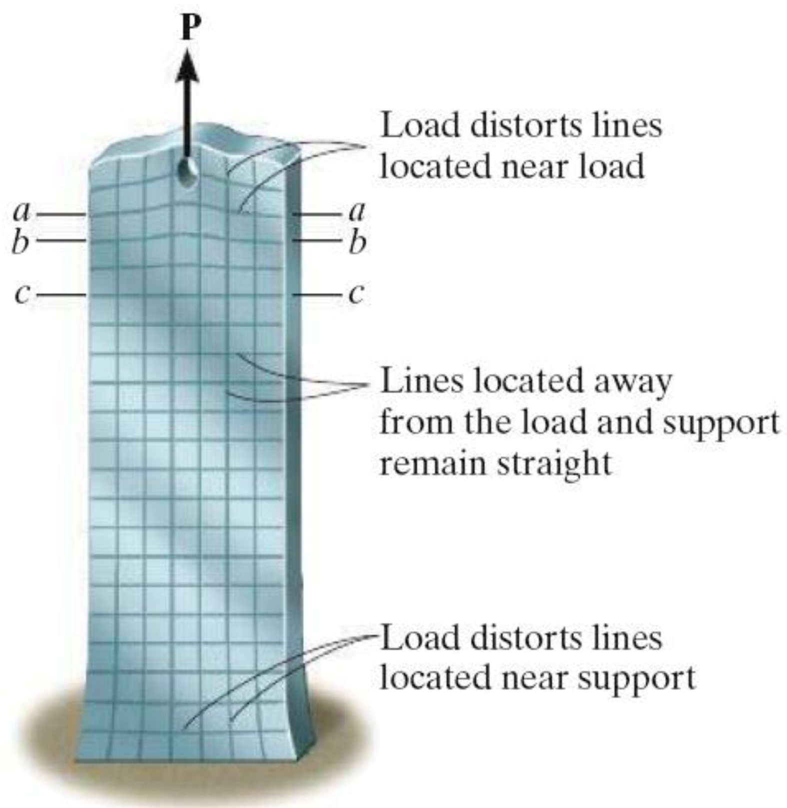
4.1 Saint-Venant's Principle

- Localized deformation occurs at each end, and the deformations decrease as measurements are taken further away from the ends
- At section *c-c*, stress reaches almost uniform value as compared to *a-a*, *b-b*.
- *C-C* is sufficiently far enough away from **P** so that localized deformation "vanishes", i.e., minimum distance.



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4.1 Saint-Venant’s Principle

- General rule: min. distance is at least equal to *largest dimension* of loaded x-section. For the bar, the min. distance is equal to width of bar.
- This behavior discovered by Barré de Saint-Venant in 1855, this the name of the principle.
- Saint-Venant Principle states that *localized effects* caused by any load acting on the body, will *dissipate/smooth out* within regions that are *sufficiently removed* from location of load.
- Thus, no need to study stress distributions at that points near application loads or support reactions

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Constant Load and Cross-Sectional Area.

In many cases

- the bar will have a constant cross-sectional area A ; and the material will
- be homogeneous, so E is constant. Furthermore,
- if a constant external force is applied at each end, Fig. 4–3 , then the internal force P throughout the length of the bar is also constant.

As a result, Eq. 4–1 can be integrated to yield

$$\boxed{\delta = \frac{PL}{AE}}$$

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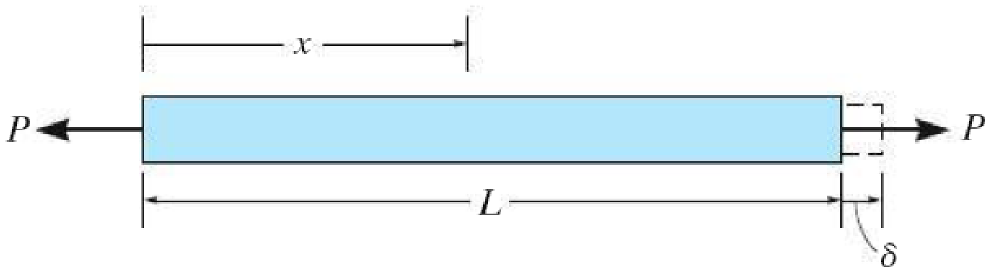
If the bar is subjected to several different axial forces along its length, or the cross-sectional area or modulus of elasticity changes abruptly from one region of the bar to the next.

The above equation can be applied to each *segment* of the bar where these quantities remain *constant.*

The displacement of one end of the bar with respect to the other is then found from the *algebraic addition* of the relative displacements of the ends of each segment. For this general case.

$$\delta = \sum \frac{PL}{AE}$$



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The vertical displacement of the rod at the top floor *B* only depends upon the force in the rod along length *AB*. However, the displacement at the bottom floor *C* depends upon the force in the rod along its entire length, *ABC*.

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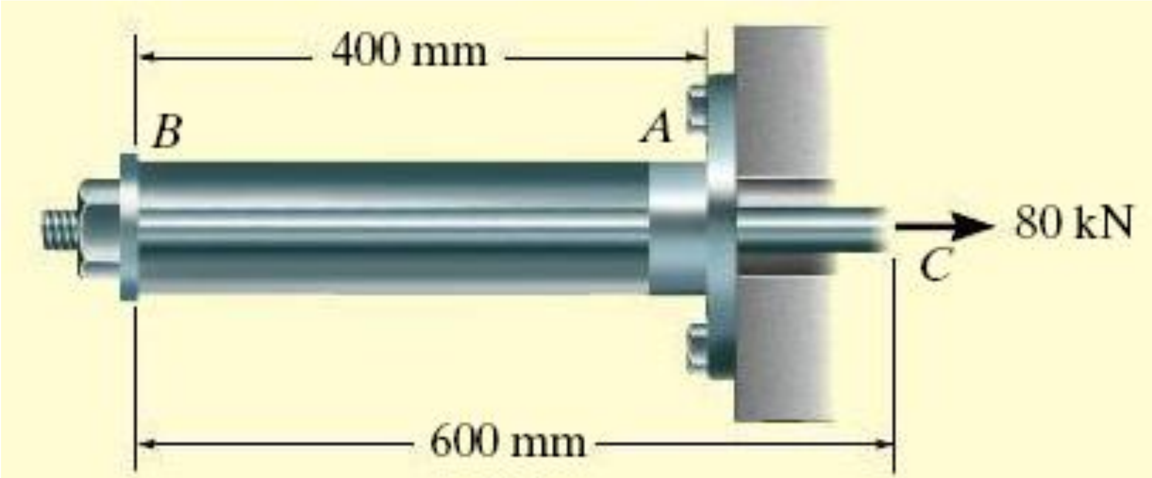
EX:- The assembly shown in Fig. 4–6 *a* consists of an aluminum tube *AB* having a cross-sectional area of 400 mm^2. A steel rod having a diameter of 10 mm is attached to a rigid collar and passes through the tube. If a tensile load of 80 kN. is applied to the rod, determine the displacement of the end *C* of the rod. Take E_{st} = 200 Gpa, E_{al} = 70 GPa.



(a)

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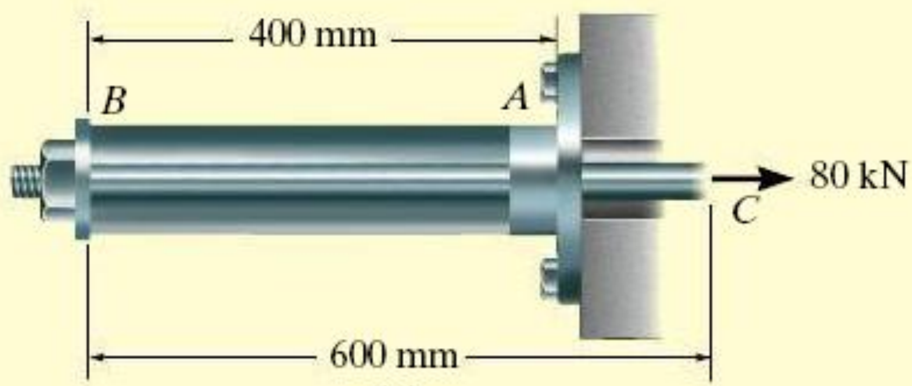
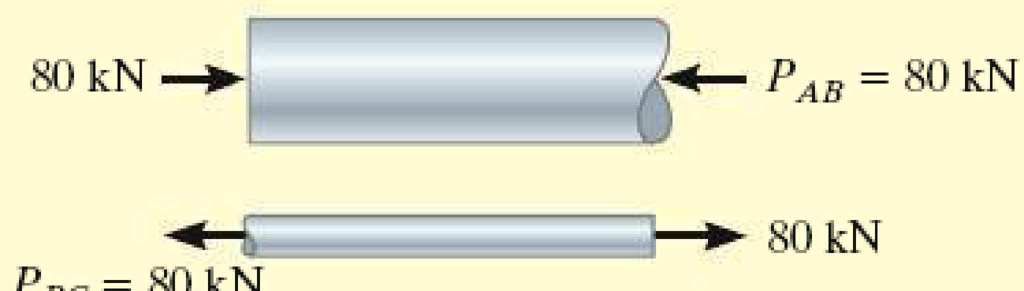
SOLUTION

Internal Force. The free-body diagram of the tube and rod segments in Fig. 4–6*b*, shows that the rod is subjected to a tension of 80 kN and the tube is subjected to a compression of 80 kN.



(a)



(b)

Displacement. We will first determine the displacement of end C with respect to end B. Working in units of newtons and meters, we have

$$\delta_{C/B} = \frac{PL}{AE} = \frac{[+80(10^3)\text{ N}]\,(0.6\text{ m})}{\pi\,(0.005\text{ m})^2[200\,(10^9)\text{ N/m}^2]} = +0.003056\text{ m} \rightarrow$$

The positive sign indicates that end C moves *to the right* relative to end B, since the bar elongates.

The displacement of end B with respect to the *fixed* end A is

$$\delta_B = \frac{PL}{AE} = \frac{[-80(10^3)\text{ N}](0.4\text{ m})}{[400\text{ mm}^2(10^{-6})\text{ m}^2/\text{mm}^2][70(10^9)\text{ N/m}^2]}$$

$$= -0.001143\text{ m} = 0.001143\text{ m} \rightarrow$$

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Here the negative sign indicates that the tube shortens, and so B moves to the *right* relative to A.

Since both displacements are to the right, the displacement of C relative to the fixed end A is therefore

$$(\overset{+}{\rightarrow}) \qquad \delta_C = \delta_B + \delta_{C/B} = 0.001143 \text{ m} + 0.003056 \text{ m}$$
$$= 0.00420 \text{ m} = 4.20 \text{ mm} \rightarrow \qquad \textit{Ans.}$$

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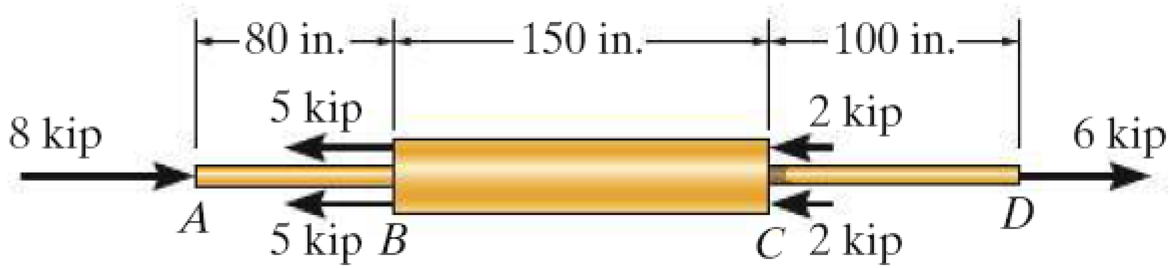
H.w.

1. The copper shaft is subjected to the axial loads shown. Determine the displacement of end A with respect to end D if the diameters of each segment are d_{AB} = 0.75 in., d_{BC} = 1 in., and d_{CD} = 0.5 in. Take $E_{cu} = 18(10^3)$ ksi.



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2. The assembly 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*. The unscratched length of each segment is shown in the figure. Neglect the size of the connections at *B* and *C*, and assume that they are rigid. E_{st} = 200 GPa, E_{al} = 70 GPa.