## FUNDAMENTAL PROBLEMS
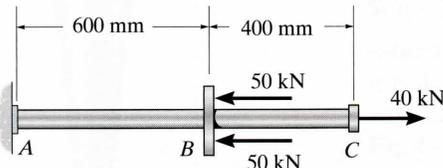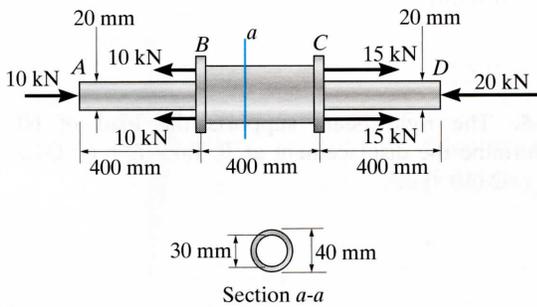
**F4–1.** The 20-mm-diameter A-36 steel rod is subjected to the axial forces shown. Determine the displacement of end C with respect to the fixed support at A.
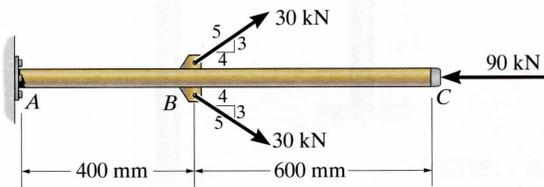


**F4–1**

**F4–2.** Segments AB and CD of the assembly are solid circular rods, and segment BC is a tube. If the assembly is made of 6061-T6 aluminum, determine the displacement of end D with respect to end A.
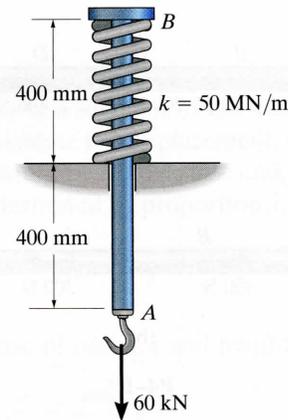


Section a-a

**F4–2**

**F4–3.** The 30-mm-diameter A992 steel rod is subjected to the loading shown. Determine the displacement of end C.



**F4–3**

**F4–4.** If the 20-mm-diameter rod is made of A-36 steel and the stiffness of the spring is $k = 50$ MN/m, determine the displacement of end A when the 60-kN force is applied.



**F4–4**
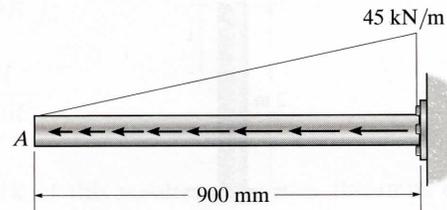
**F4–5.** The 20-mm-diameter 2014-T6 aluminum rod is subjected to the uniform distributed axial load. Determine the displacement of end A.
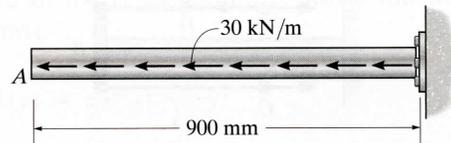


**F4–5**

**F4–6.** The 20-mm-diameter 2014-T6 aluminum rod is subjected to the triangular distributed axial load. Determine the displacement of end A.
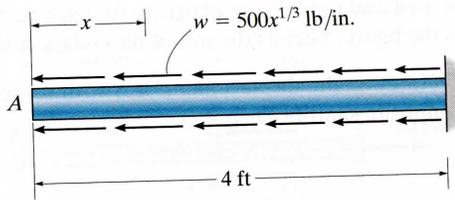


**F4–6**

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**4–2.** T
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8 kip

**4–6.** The bar has a cross-sectional area of 3 in², and $E = 35 (10^3)$ ksi. Determine the displacement of its end $A$ when it is subjected to the distributed loading.



$w = 500x^{1/3}$ lb/in.

4 ft

**Prob. 4–6**

**4–7.** If $P_1 = 50$ kip and $P_2 = 150$ kip, determine the vertical displacement of end $A$ of the high strength precast concrete column.
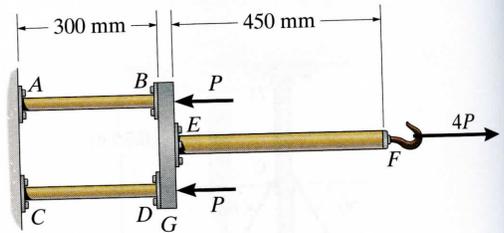
*__4–8.__ If the vertical displacements of end $A$ of the high strength precast concrete column relative to $B$ and $B$ relative to $C$ are 0.08 in. and 0.1 in., respectively, determine the magnitudes of $P_1$ and $P_2$.



6 in.

6 in.
Section *a-a*

10 in.

10 in.
Section *b-b*
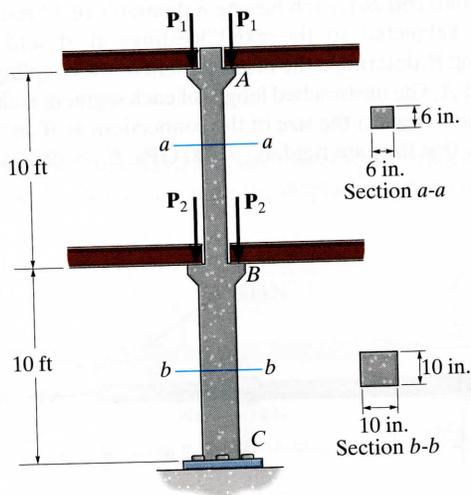
**Probs. 4–7/8**

**4–9.** The assembly consists of two 10-mm diameter red brass C83400 copper rods $AB$ and $CD$, a 15-mm diameter 304 stainless steel rod $EF$, and a rigid bar $G$. If $P = 5$ kN, determine the horizontal displacement of end $F$ of rod $EF$.
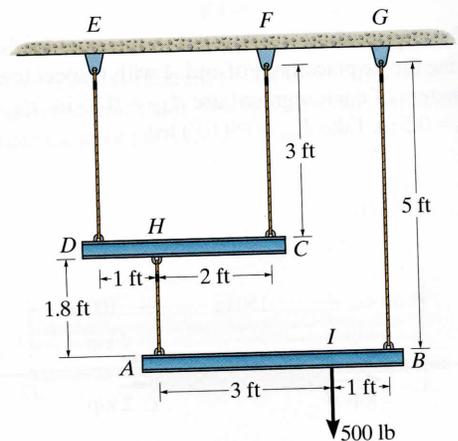
**4–10.** The assembly consists of two 10-mm diameter red brass C83400 copper rods $AB$ and $CD$, a 15-mm diameter 304 stainless steel rod $EF$, and a rigid bar $G$. If the horizontal displacement of end $F$ of rod $EF$ is 0.45 mm, determine the magnitude of $P$.



300 mm    450 mm

$P$
$4P$

$P$

**Probs. 4–9/10**

**4–11.** The load is supported by the four 304 stainless steel wires that are connected to the rigid members $AB$ and $DC$. Determine the vertical displacement of the 500-lb load if the members were originally horizontal when the load was applied. Each wire has a cross-sectional area of 0.025 in².

*__4–12.__ The load is supported by the four 304 stainless steel wires that are connected to the rigid members $AB$ and $DC$. Determine the angle of tilt of each member after the 500-lb load is applied. The members were originally horizontal, and each wire has a cross-sectional area of 0.025 in².



$E$    $F$    $G$

3 ft

5 ft

$D$    $H$    $C$
1 ft    2 ft

1.8 ft

$A$    $I$    $B$
3 ft    1 ft

500 lb

**Probs. 4–11/12**

**4–13**
$CB$
fron
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**4-26.** Determine the elongation of the tapered A992 steel shaft when it is subjected to an axial force of 18 kip. *Hint:* Use the result of Prob. 4–23.

$r_1 = 0.5$ in.   $r_2 = 2$ in.   $r_1 = 0.5$ in.

18 kip   4 in.   20 in.   4 in.   18 kip
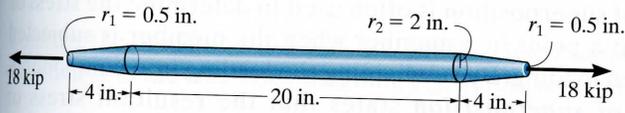
**Prob. 4–26**

**4-27.** The circular bar has a variable radius of $r = r_0e^{ax}$ and is made of a material having a modulus of elasticity of $E$. Determine the displacement of end $A$ when it is subjected to the axial force **P**.

$L$

$B$

$x$

$r = r_0 e^{ax}$

$r_0$

$A$   **P**
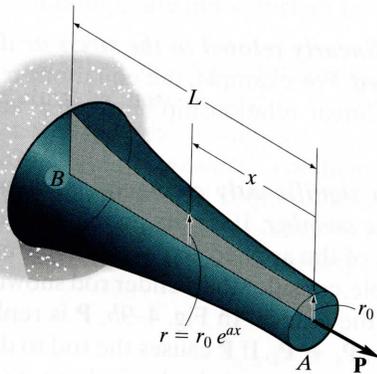
**Prob. 4–27**

***4-28.** Bone material has a stress–strain diagram that can be defined by the relation $\sigma = E[\epsilon/(1 + kE\epsilon)]$, where $k$ and $E$ are constants. Determine the compression within the length $L$ of the bone, where it is assumed the cross-sectional area $A$ of the bone is constant.

$P$

$L$

$P$

**Prob. 4–28**

**4-29.** The weight of the kentledge exerts an axial force of $P = 1500$ kN on the 300-mm diameter high-strength concrete bore pile. If the distribution of the resisting skin friction developed from the interaction between the soil and the surface of the pile is approximated as shown, and the resisting bearing force **F** is required to be zero, determine the maximum intensity $p_0$ kN/m for equilibrium. Also, find the corresponding elastic shortening of the pile. Neglect the weight of the pile.

**P**

$p_0$

12 m

**F**
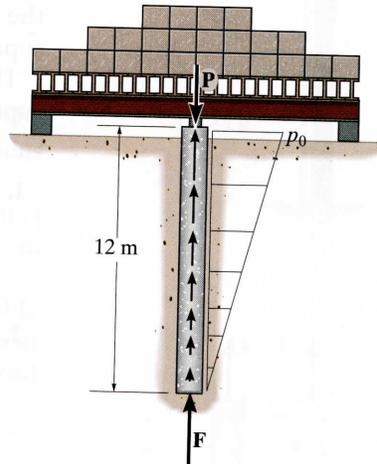
**Prob. 4–29**

**4-30.** The weight of the kentledge exerts an axial force of $P = 1500$ kN on the 300-mm diameter high-strength concrete bore pile. If the distribution of the resisting skin friction developed from the interaction between the soil and the surface of the pile is approximated as shown, determine the resisting bearing force **F** for equilibrium. Take $p_0 = 180$ kN/m. Also, find the corresponding elastic shortening of the pile. Neglect the weight of the pile.

**P**

$p_0$

12 m

**F**
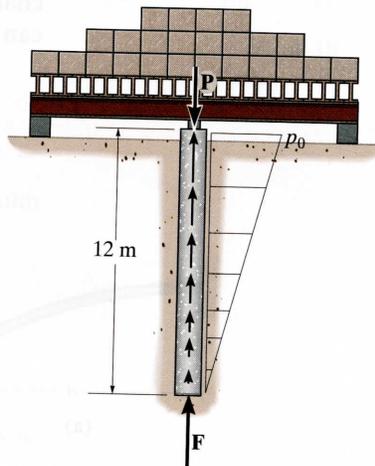
**Prob. 4–30**

**4–38.** The load of 2800 lb is to be supported by the two essentially vertical A-36 steel wires. If originally wire $AB$ is 60 in. long and wire $AC$ is 40 in. long, determine the force developed in each wire after the load is suspended. Each wire has a cross-sectional area of 0.02 in$^2$.

**4–39.** The load of 2800 lb is to be supported by the two essentially vertical A-36 steel wires. If originally wire $AB$ is 60 in. long and wire $AC$ is 40 in. long, determine the cross-sectional area of $AB$ if the load is to be shared equally between both wires. Wire $AC$ has a cross-sectional area of 0.02 in$^2$.
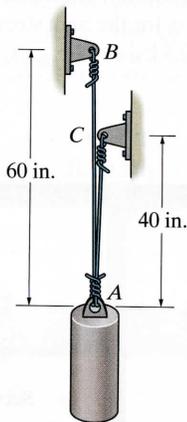


**Probs. 4–38/39**

**\*4–40.** The rigid member is held in the position shown by three A-36 steel tie rods. Each rod has an unstretched length of 0.75 m and a cross-sectional area of 125 mm$^2$. Determine the forces in the rods if a turnbuckle on rod $EF$ undergoes one full turn. The lead of the screw is 1.5 mm. Neglect the size of the turnbuckle and assume that it is rigid. *Note:* The lead would cause the rod, when *unloaded*, to shorten 1.5 mm when the turnbuckle is rotated one revolution.
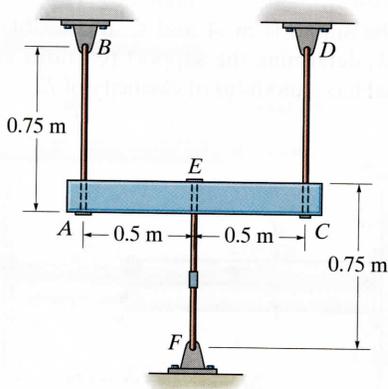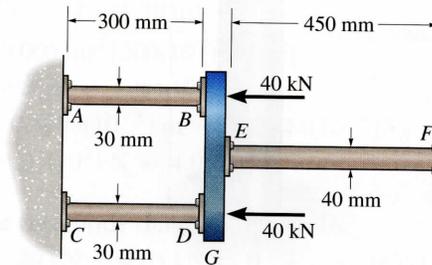


**Prob. 4–40**

**4–41.** The 2014-T6 aluminum rod $AC$ is reinforced with the firmly bonded A992 steel tube $BC$. If the assembly fits snugly between the rigid supports so that there is no gap at $C$, determine the support reactions when the axial force of 400 kN is applied. The assembly is attached at $D$.

**4–42.** The 2014-T6 aluminum rod $AC$ is reinforced with the firmly bonded A992 steel tube $BC$. When no load is applied to the assembly, the gap between end $C$ and the rigid support is 0.5 mm. Determine the support reactions when the axial force of 400 kN is applied.
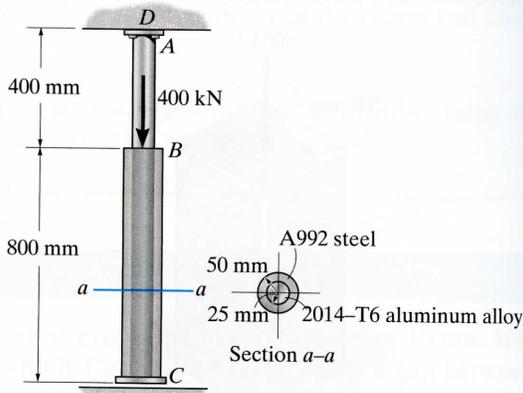


**Probs. 4–41/42**

**4–43.** The assembly consists of two red brass C83400 copper rods $AB$ and $CD$ of diameter 30 mm, a stainless 304 steel alloy rod $EF$ of diameter 40 mm, and a rigid cap $G$. If the supports at $A$, $C$ and $F$ are rigid, determine the average normal stress developed in rods $AB$, $CD$ and $EF$.



**Prob. 4–43**

**\*4–44.** copper r 304 stair and a rig have a s normal s

**4–45.** T through outer dia A-36 ste when a f caps are

**4–46.** I initially and $D$ w is made

**4–75.** The 40-ft-long A-36 steel rails on a train track are laid with a small gap between them to allow for thermal expansion. Determine the required gap $\delta$ so that the rails just touch one another when the temperature is increased from $T_1 = -20°F$ to $T_2 = 90°F$. Using this gap, what would be the axial force in the rails if the temperature were to rise to $T_3 = 110°F$? The cross-sectional area of each rail is 5.10 in$^2$.
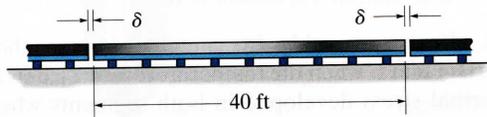
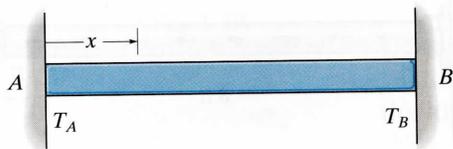

**Prob. 4–75**

*4–76.** The device is used to measure a change in temperature. Bars $AB$ and $CD$ are made of A-36 steel and 2014-T6 aluminum alloy, respectively. When the temperature is at 75°F, $ACE$ is in the horizontal position. Determine the vertical displacement of the pointer at $E$ when the temperature rises to 150°F.
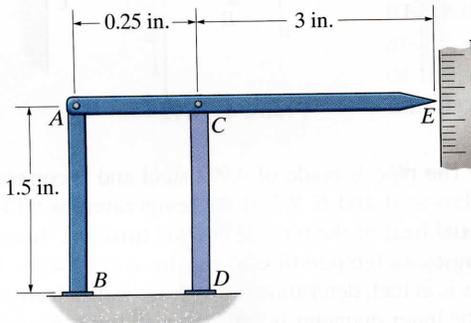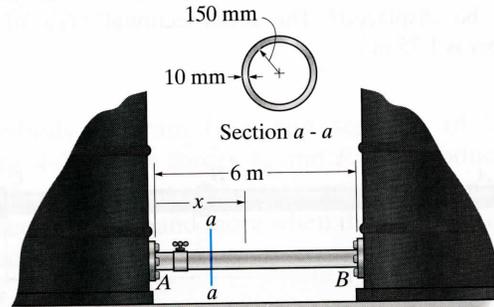


**Prob. 4–76**

**4–77.** The bar has a cross-sectional area $A$, length $L$, modulus of elasticity $E$, and coefficient of thermal expansion $\alpha$. The temperature of the bar changes uniformly along its length from $T_A$ at $A$ to $T_B$ at $B$ so that at any point $x$ along the bar $T = T_A + x(T_B - T_A)/L$. Determine the force the bar exerts on the rigid walls. Initially no axial force is in the bar and the bar has a temperature of $T_A$.



**Prob. 4–77**

**4–78.** When the temperature is at 30°C, the A-36 steel pipe fits snugly between the two fuel tanks. When fuel flows through the pipe, the temperatures at ends $A$ and $B$ rise to 130°C and 80°C, respectively. If the temperature drop along the pipe is linear, determine the average normal stress developed in the pipe. Assume each tank provides a rigid support at $A$ and $B$.



**Prob. 4–78**

**4–79.** When the temperature is at 30°C, the A-36 steel pipe fits snugly between the two fuel tanks. When fuel flows through the pipe, the temperatures at ends $A$ and $B$ rise to 130°C and 80°C, respectively. If the temperature drop along the pipe is linear, determine the average normal stress developed in the pipe. Assume the walls of each tank act as a spring, each having a stiffness of $k = 900$ MN/m.

*4–80.** When the temperature is at 30°C, the A-36 steel pipe fits snugly between the two fuel tanks. When fuel flows through the pipe, it causes the temperature to vary along the pipe as $T = (\frac{5}{3}x^2 - 20x + 120)°C$, where $x$ is in meters. Determine the normal stress developed in the pipe. Assume each tank provides a rigid support at $A$ and $B$.
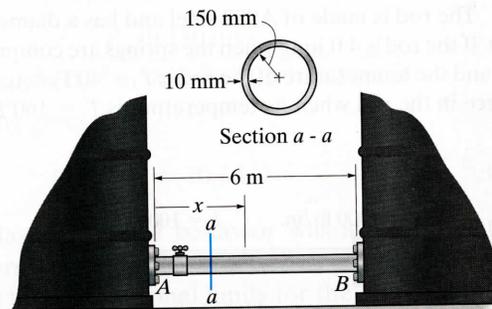


**Probs. 4–79/80**

**4–81.**
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**4–82.**
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**4–83.**
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