E APPENDIX

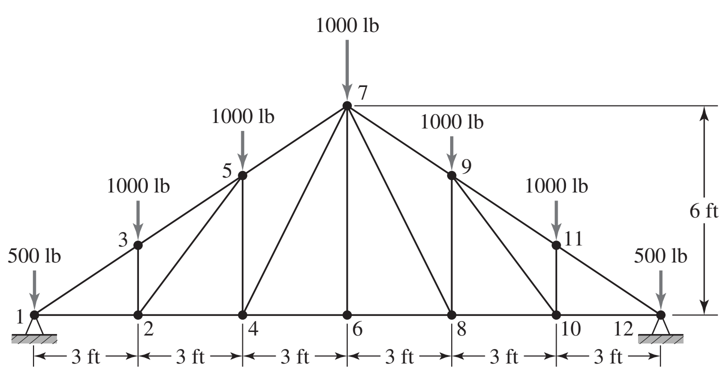
Problems for Computer Solution

The following problems are intended for solution using finite element analysis software. In general, the problems associated with Chapters 3, 4, and 9 can be solved using the FEPC software (Appendix D) if another software package is not available. The instructor may choose to change loading, material properties, or geometry for any of these problems at his or her discretion.

E.1 CHAPTER 3

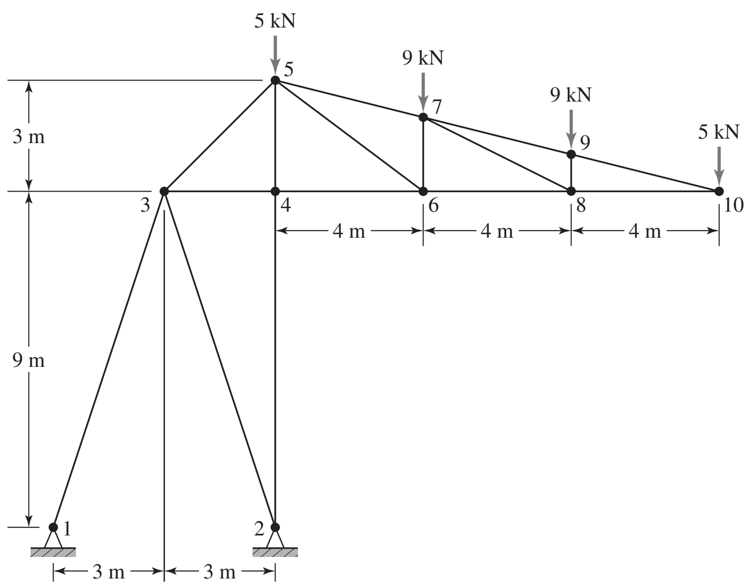
Problems E3.1–E3.7 involve two-dimensional trusses to be modeled using the bar element (in some analysis software this may be called a *bar, link, spar,* or *truss element*). In each problem, determine the magnitude and location of the maximum deflection, the stress in each member, and the reaction forces. Use the computed reaction forces to check the equilibrium. Node numbers, where included, are for reference only and can be changed at the analyst's discretion.

E3.1 Each member is steel having $E = 30(10^6)$ psi and the cross-sectional area is 1.2 in.^{2}



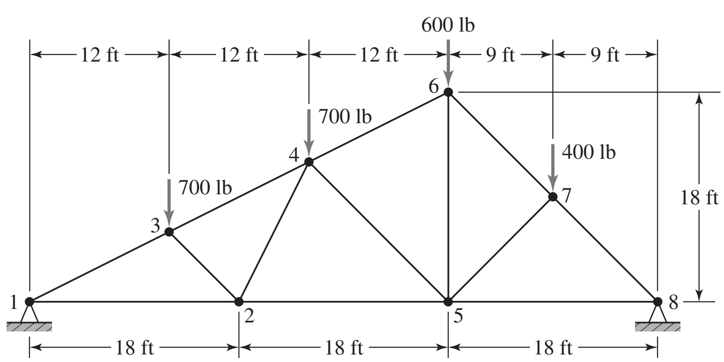
Problem E3.1

E3.2 All members are hollow circular tubing having outside diameter 100 mm and wall thickness 10 mm. The modulus of elasticity is 207 GPa.



Problem E3.2

E3.3 All truss members are 2″ × 4″ lumber having $E = 3(10^6)$ psi.

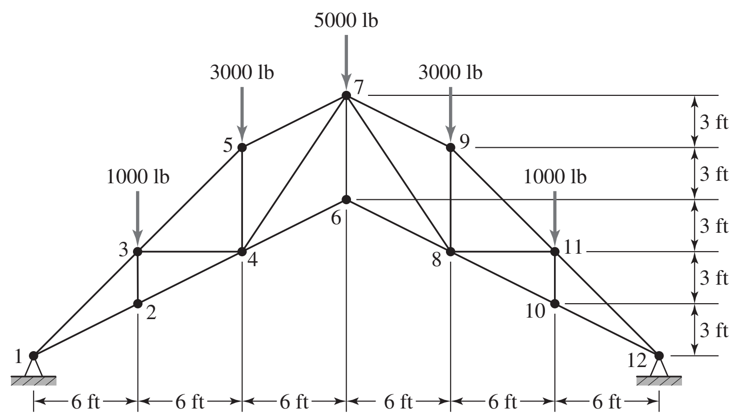


Problem E3.3

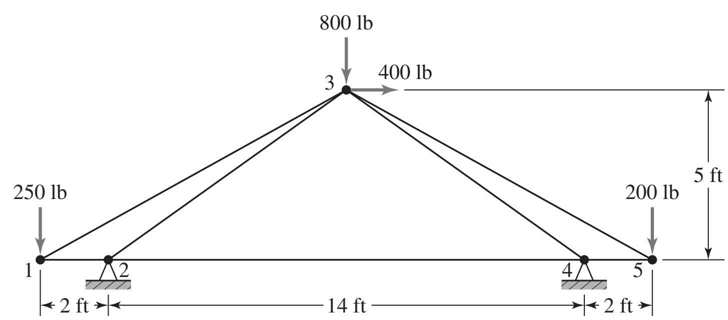
E3.4 The truss members are square tubular aluminum members having 2.5″ outside dimension and 0.25″ wall thickness. The modulus of elasticity is 10^7 psi.

E3.5 All members are identical with cross-sectional area of 1.6 in.^{2} and modulus of elasticity $15(10^6)$ psi.

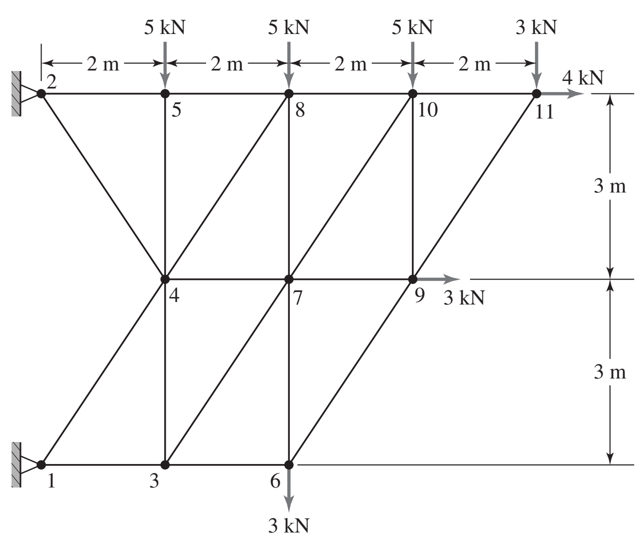
E3.6 The horizontal members are solid, square steel bars having basic dimension 30 mm; all other members are flat steel sheet stock 6 mm thick by 50 mm wide. Use $E = 207$ GPa. Are the computed stresses reasonable for structural steel?



Problem E3.4

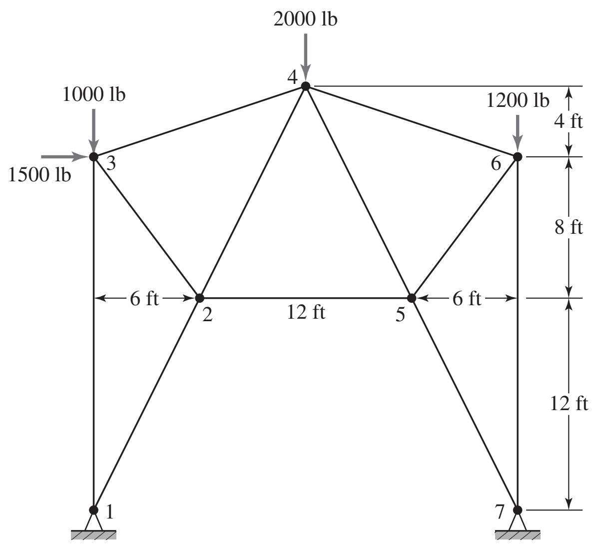


Problem E3.5



Problem E3.6

E3.7 The truss is composed of solid circular steel members 2″ in diameter. The modulus of elasticity is $30(10^6)$ psi, Other than deflection and stress, what concerns should be considered with this truss? Does your answer relate to the relatively low computed stress values?



Problem E3.7

E.2 CHAPTER 4

The problems in this section deal with frame structures (that is, structures in which the joints are fixed and transmit bending moment, unlike the pin joint assumption of trusses).

E4.1–E4.7 Solve problems E3.1–E3.7, respectively, assuming that the joints are fixed as in welded or riveted joints. Additional required information is as follows.
For E3.1,

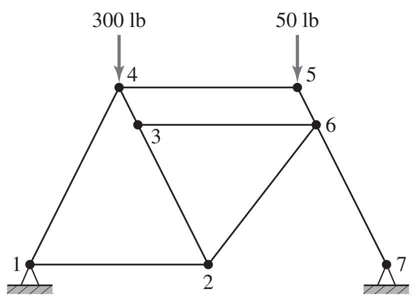
$$I_z = 0.4 \text{ in.}^4$$

For E3.5,

$$I_z = 0.53 \text{ in.}^4$$

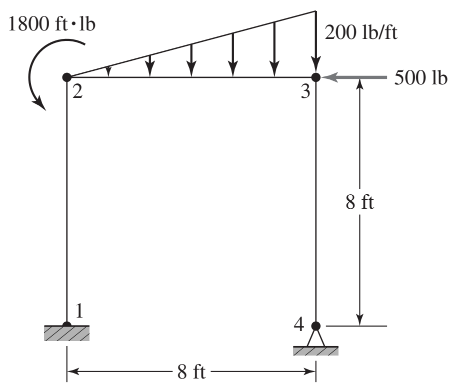
E4.8 The figure shows a basic model of a bicycle frame. All members are 1″ diameter circular tubing having wall thickness 0.1″ and are made of titanium, which has a modulus of elasticity of $15(10^6)$ psi. Determine the maximum deflection and the stress in each member. The nodal coordinates (in inches) are as follows:

	x	*y*
1	0	0
2	18	0
3	11	14
4	9	18
5	27	18
6	29	14
7	36	0



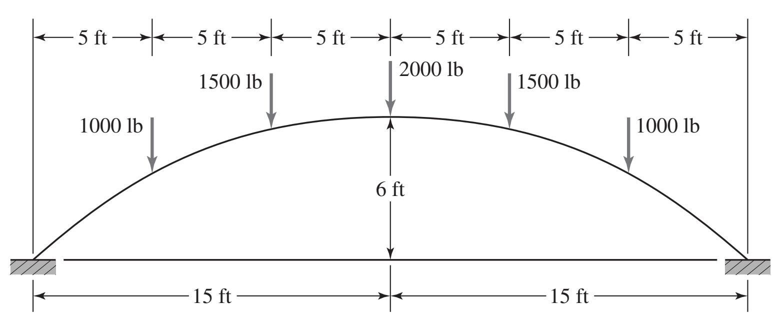
Problem E4.8

E4.9 Determine the maximum deflection and maximum stress in the frame structure shown if the structural members are 1″ diameter, solid aluminum tubes for which $E = 10(10^6)$ psi.



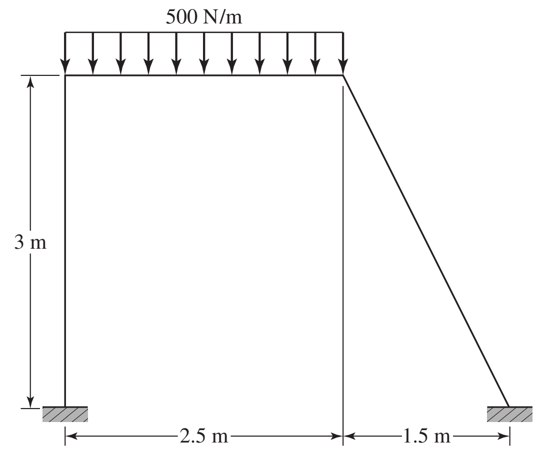
Problem E4.9

E4.10 The figure shows an arch that is the main support structure for a footbridge. The arch is constructed of standard AISC 6I17.5 I-beams (height = 6 in.; $A = 5.02$ in.^{2}; $I_z = 26.0$ in.^{4}). Use straight beam elements to model this bridge and examine convergence of solution as the number of elements is increased from 6 to 12 to 18. In examining convergence, look at both deflection and stress. Also note that, owing to the direction of loading, axial effects must be included. $E = 30(10^6)$ psi.



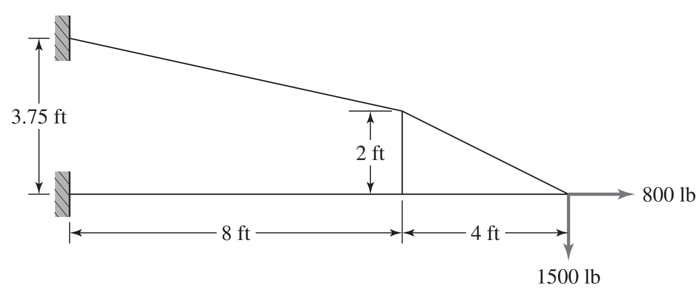
Problem E4.10

E4.11 The frame structure shown is composed of 10 mm × 10 mm solid square members having $E = 100$ GPa. Determine the maximum deflection, maximum slope, and maximum stress.



Problem E4.11

E4.12 The structure shown is a model of the support for a freeway light post. For uniformity in wind loading, the structural members are circular. The outside diameter of each member is 3.0″ and wall thickness is 0.25″. Compute the deflection at each structural joint and determine maximum stresses. Examine the effects on your solution of using more elements (i.e., refine the mesh). $E = 10^7$ psi.

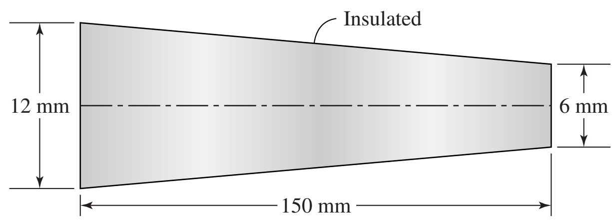


Problem E4.12

E.3 CHAPTER 7

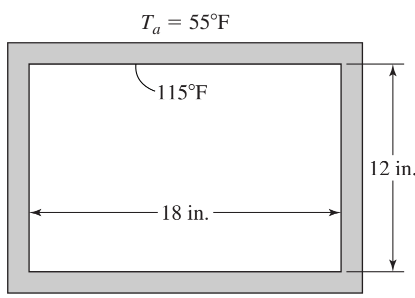
E7.1 A tapered circular heat transfer pin (known as a *pin fin*) is insulated all around its circumference, as shown. The large end ($D = 12$ mm) is maintained at a constant temperature of 90°C, while the smaller end ($D = 6$ mm) is at 30°C. Determine the steady-state heat flow through the pin using a mesh of straight elements. Thermal conductivity of the material is $k = 200$ W/m-°C.

E7.2 A rectangular duct in a home heating system has dimensions 12″ × 18″ as shown. The duct is insulated with a uniform layer of fiberglass 1″ thick. The



Problem E7.1

duct (steel sheet metal) is maintained at a constant temperature of 115°F. The ambient air temperature around the duct is 55°F.

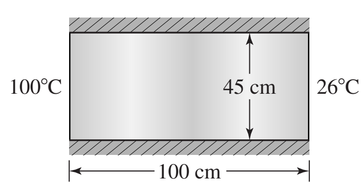


Problem E7.2

(a) Calculate the temperature distribution in the insulation and the heat loss per unit length to the surrounding air. Thermal conductivity of the insulation is uniform in all directions and has value $k = 0.025$ Btu/hr-ft-°F; the convection coefficient to the ambient air is $h = 5$ Btu/hr-ft^2-°F.

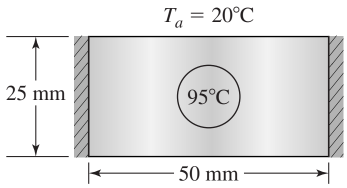
(b) Repeat the calculations for an insulation thickness of 2 in.

E7.3 The figure represents a cross section of a long bar insulated on the upper and lower surfaces; hence, the problem is to be treated as two dimensional on a per unit length basis. The left edge is maintained at constant temperature of 100°C and the right edge is maintained at 26°C. The material has uniform conductivity $k = 35$ W/m-°C. Determine the temperature distribution and the steady-state heat flow rate. What element should you use? (Triangular, square? Perform the analysis with different elements to observe differences in the solutions.) Refine the mesh and examine convergence.



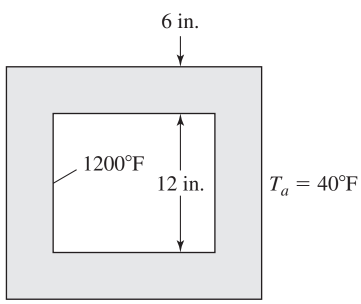
Problem E7.3

E7.4 A thin copper tube (12 mm diameter) containing water at an average temperature of 95°C is imbedded in a long slender solid slab, as shown. The vertical edges are insulated. The horizontal edges are exposed to an ambient temperature of 20°C and the associated convection coefficient is $h = 20$ W/m^2-°C. The material has uniform conductivity $k = 200$ W/m-°C. Compute the net steady-state heat transfer rate and the temperature distribution in the cross section.



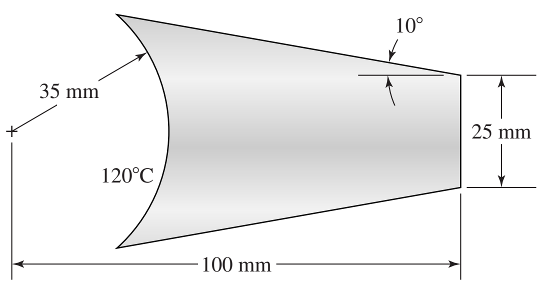
Problem E7.4

E7.5 The figure shows a horizontal cross section of a chimney exhausting the gases generated by a wood stove. The flue is insulated with firebrick 6″ thick and having uniform conductivity $k = 2.5$ Btu/hr-ft-°F. The chimney is surrounded by air at ambient temperature 40°F and the convection coefficient is 5 Btu/hr-ft^2-°F. Determine the temperature distribution in the firebrick and the heat loss per unit length.



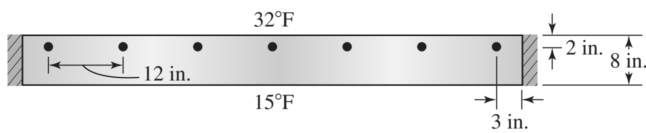
Problem E7.5

E7.6 The heat transfer fin shown is attached to a pipe conveying a fluid at average temperature 120°C. The thickness of the fin is 3 mm. The fin is surrounded by air at temperature 30°C and subject to convection on all surfaces with $h = 20$ W/m^2-°C. The fin material has uniform conductivity $k = 50$ W/m-°C. Determine the heat transfer rate from the fin and the temperature distribution in the fin.



Problem E7.6

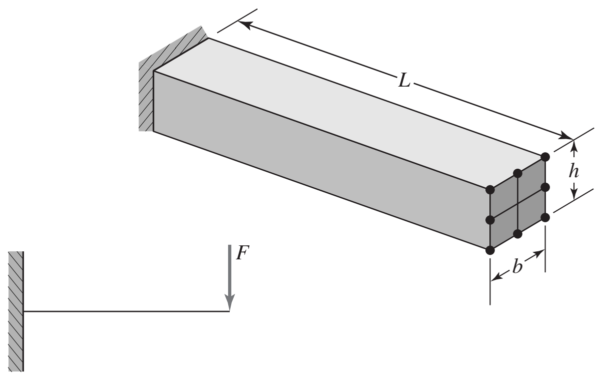
E7.7 The cross section shown is of a campus footbridge, having embedded heat cables to prevent ice accumulation. The vertical edges are insulated and the horizontal surfaces are at the steady temperatures shown. The material has uniform conductivity $k = 0.6$ Btu/hr-ft-°F and the cables have source strength 200 Btu/hr-in. Compute the net heat transfer rate and the temperature distribution.



Problem E7.7

E.4 CHAPTER 9

E9.1 The cantilever beam shown is subjected to a concentrated load F applied at the end. Model this beam using three-dimensional brick elements and compare the finite element solution to elementary beam theory. How do you apply the concentrated load in the *FE* model?



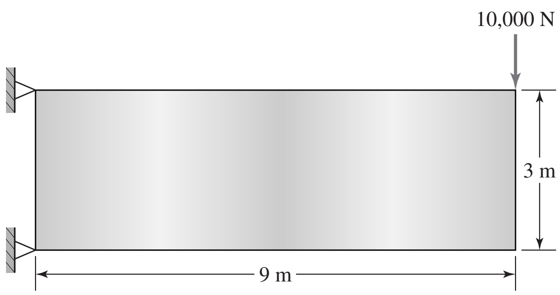
Problem E9.1

E9.2 Refer to a standard mechanical design text and obtain the geometric parameters of a standard involute gear tooth profile. Assuming a tooth to be fixed at the root diameter, determine the stress distribution in a gear tooth when the load acts at (a) at the tip of the tooth and (b) the pitch diameter. (c) Are your results in accord with classic geartooth theory?

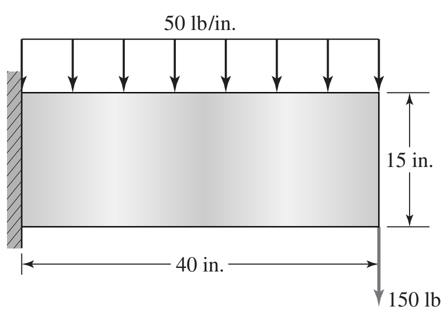
E9.3 A flat plate of thickness 25 mm is loaded as shown; the material has modulus of elasticity $E = 150$ GPa and Poisson's ratio 0.3. Determine the maximum deflection, maximum stress, and the reaction forces assuming a state of plane stress.

E9.4 Repeat Problem E9.3 if the thickness varies from 25 mm at the left end to 15 mm at the right.

E9.5 A thin, 0.5″ thickness, steel plate is subjected to the loading shown. Determine the maximum displacement and the stress distribution in the plate. Use $E = 30(10^6)$ and Poisson's ratio 0.3.

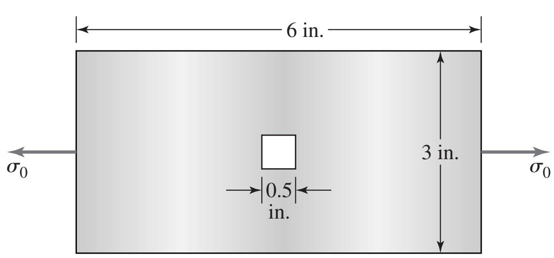


Problem E9.3



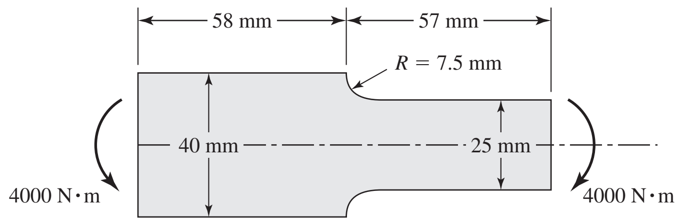
Problem E9.5

E9.6 A uniform thin plate subjected to a uniform tensile stress as shown has a central rectangular opening. Use the finite element method to determine the stress concentration factor arising from the cutout. Use the material properties of steel. Would your results change if you use the material properties of aluminum? Why? Why not?



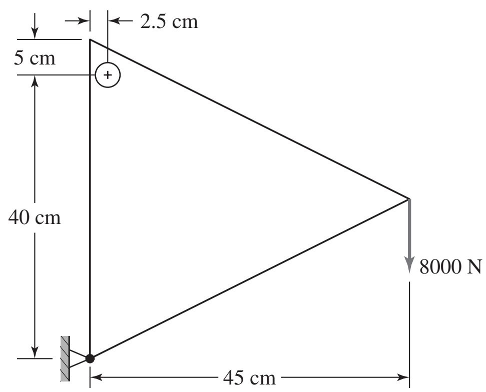
Problem E9.6

E9.7 The figure shows a common situation in mechanical design. A fillet radius is used to smooth the transition between sections having different dimensions. Use the finite element method to determine the stress concentration factor arising from the fillet radius at the section change. Material thickness is 0.25″ and $E = 15(10^6)$ psi. How do you model the moment loading?



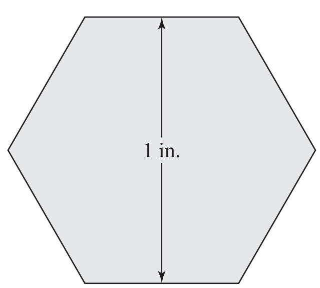
Problem E9.7

E9.8 The gusset plate shown is attached at the upper left via a 1.5 cm diameter rivet and held free at the lower left (model as a pin connection). The plate is loaded as shown. Assuming that the rivet is rigid, compute the stress distribution around the circumference of the rivet. Also determine the maximum deflection. The gusset has thickness 14 mm, modulus of elasticity 207 GPa, and Poisson's ratio 0.28.



Problem E9.8

E9.9 Noncircular shaft sections are often used for quick-change couplings. The figure shows a hexagonal cross section used for such a purpose. The shaft length is 6″ and subjected to a net torque of 2800 in.-lb. If the material is steel, compute the total angle of twist. (Note: It is highly likely that your *FE* software will have no element directly applicable to this problem. Analogy may be required.)

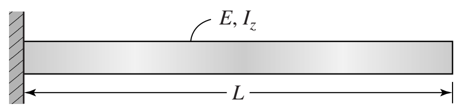


Problem E9.9

E.5 CHAPTER 10

E10.1–10.7 For each truss of Problems E3.1–E3.7 and E4.1–4.7, determine the lowest five natural frequencies and mode shapes. How do these vary with pin joint versus rigid frame assumptions? (Note that, where a material is not specified, the instructor will provide the density value.)

E10.8 Use the modal analysis capability of your finite element software to determine the natural frequencies and mode shapes of the cantilevered beam shown. Use mesh refinement to observe convergence of the frequencies. Compare with published values in many standard vibration texts. What do the higher frequencies represent? How many frequencies can you calculate?



Problem E10.8