UNIVERSITY OF WATERLOO
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

CivE 105: Mechanics 2

W2019

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Office Hours: **12:20 am – 1:20 pm, Tuesdays and Fridays**

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3. Important and helpful information on First-Year Engineering can be found at:

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Course Outline

Text Book: R.C. Hibbeler, 2017, *Mechanics*, University of Waterloo, Pearson Collections, ISBN 10: 1323520104, ISBN-13: 9781323520109.

	Topics	Corresponding Sections in the Text Book	Examples
Statics	**1. Force Systems and Equilibrium in 2-D**		
	2-D force systems (Review)	Chapters 1-3 (2-D force systems), Notes	E1-1
	2-D equilibrium (Review)	4.1—4.4 pp.177-204, Notes	E1-2, E1-3, E1-4, E1-5, E1-6
	Friction	4.7 Characteristics of Dry Friction, p.220	E1-7, E1-8, E1-9
		4.8 Problems Involving Dry Friction, p.224	
	2. Structural Analysis		
	Simple trusses	5.1 Simple trusses, p.251	
		5.3 Zero-force members, p.260	
	Method of joints	5.2 The method of joints, p.254	E2-1, E2-2
	Method of sections	5.4 The method of sections, p.267	E2-2, E2-3
	Frames	5.5 Frames and machines, p.276	E2-4, E2-5, E2-6
	3. Geometric Properties and Distributed Forces		
	Center of gravity & centroid	6.1 Center of gravity and centroid of a body, p.305	E3-1
		6.2 Composite bodies, p.319	E3-2

	Distributed forces	3.9 Reduction of a simple distributed loading, p.153	E3-3
	Moment of inertia	6.3 Moments of inertia for areas, p.328	E3-4
		6.4 Parallel-axis theorem for an area, p.329	E3-5, E3-6
		6.5 Moments of inertia for composite areas, p.337	
	4. Fluid Statics (Notes)		
	Pressure	17.1 Pressure, p.931	E4-1
		17.2 Absolute and gage pressure, p.934	
		17.3 Static pressure variation, p.936	
		17.4 Pressure variation for incompressible fluids, p.937	
		17.6 Measurement of static pressure, p.942	E4-2
	Fluid Statics	17.7 Hydrostatic forces on a plane surface—formula method, p.950	E4-3, E4-4, E4-5, E4-6
		17.8 Hydrostatic forces on a plane surface—geometrical method, p.956	
		17.10 Hydrostatic forces on an inclined plane or curved surface determined by projection, p.964	E4-7
Solid Mechanics	**5. Stress and Strain**		
		7.2 Internal resultant loadings, p.354	E5-1
	Normal and shear stresses	7.3 Stress, p.368	
		7.4 Average normal stress in an axially loaded bar, p.370	E5-2, E5-3
		7.5 Average shear stress, p.377	
		7.6 Allowable stress design, p.388	E5-4, E5-5
	Deformation and strain	7.7 Deformation, p.403	E5-6, E5-7
		7.8 Strain, p.404	
	Stress-strain relationship	8.2 The stress-strain diagram, p.433	
		8.3 Stress-strain behaviour of ductile and brittle materials, p.437	
		8.5 Poisson's ratio, p.450	E5-8
	6. Axial Loading		
	Introduction	9.1 Saint-Venant's principle, p.467	
	Axial deformation	9.2 Elastic deformation of an axially loaded member, p.469	E6-1
	Superposition and statically indeterminate members	9.3 Principle of superposition, p.484	E6-2, E6-3, E6-4
		9.4 Statically indeterminate axially loaded member, p.484	
		9.5 Force method of analysis for axially loaded members, p.491	
	Thermal stress	9.6 Thermal stress, p.497	E6-5, E6-6, E6-7
	7. Bending		
	Shear and moment diagrams	11.1 Shear and moment diagrams, p.565	E7-1, E7-2
		11.2 Graphical method for shear and moment diagrams, p.572	E7-1, E7-2, E7-3
	Bending stress	11.3 Bending deformation of a straight member, p.591	E7-4, E7-5
		11.4 The flexure formula, p.595	

Grading Schemes

	Scheme 1	**Scheme 2**
Assignments	**20%**	**20%**
Mid-term Exam	20%	10%
Final Exam	60%	70%
	100%	**100%**

Assignments

Assignment No. 1   Due: 6:00 p.m., Friday, January 18, 2019

Equilibrium in 2-D; friction

1. The uniform slender bar of length $3r$ and mass m rests against the circular surface as shown. Determine the normal force at the contact point C and the magnitude of the ideal pivot reaction at O. (Answer: $N_C = 0.433\,mg$, $R_O = 0.869\,mg$)

2. The uniform bar OC of length L pivots freely about a horizontal axis through O. If the spring of stiffness k is unstretched when C is coincident with A, determine the tension T required to hold the bar in the position shown. The diameter of the small pulley at D is negligible.
(Answer: $T = 0.1176\,kL + 0.366\,mg$)

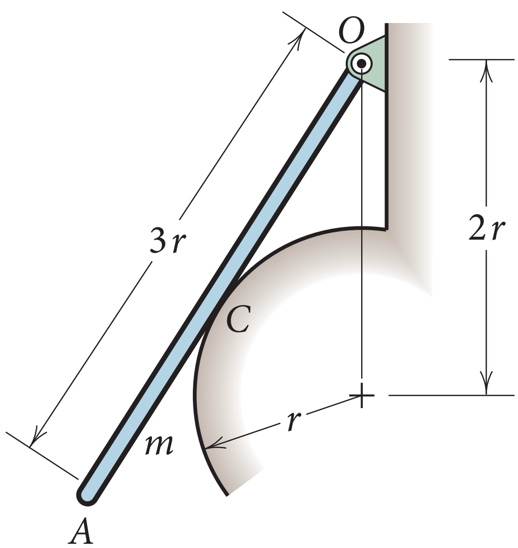


Figure 1

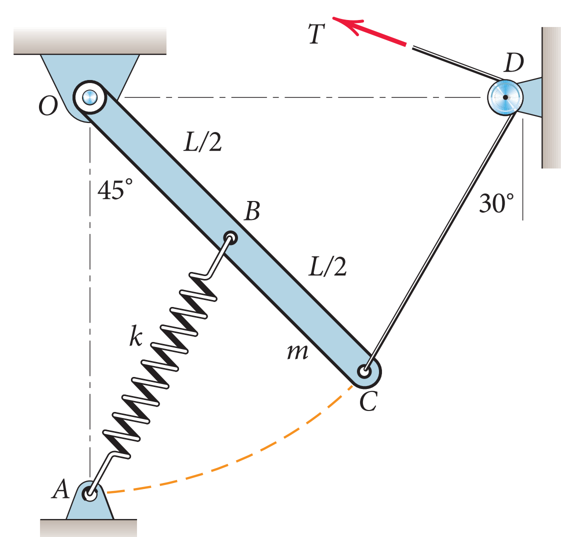


Figure 2

3. The portable floor crane in the automotive shop is lifting a 420-lb engine. For the position shown compute the magnitude of the force supported by the pin at C and the oil pressure P against the 3.20-in-diameter piston of the hydraulic-cylinder unit AB.
(Answer: $R_C = 1276$ lb, $P = 209$ lb/in^2)

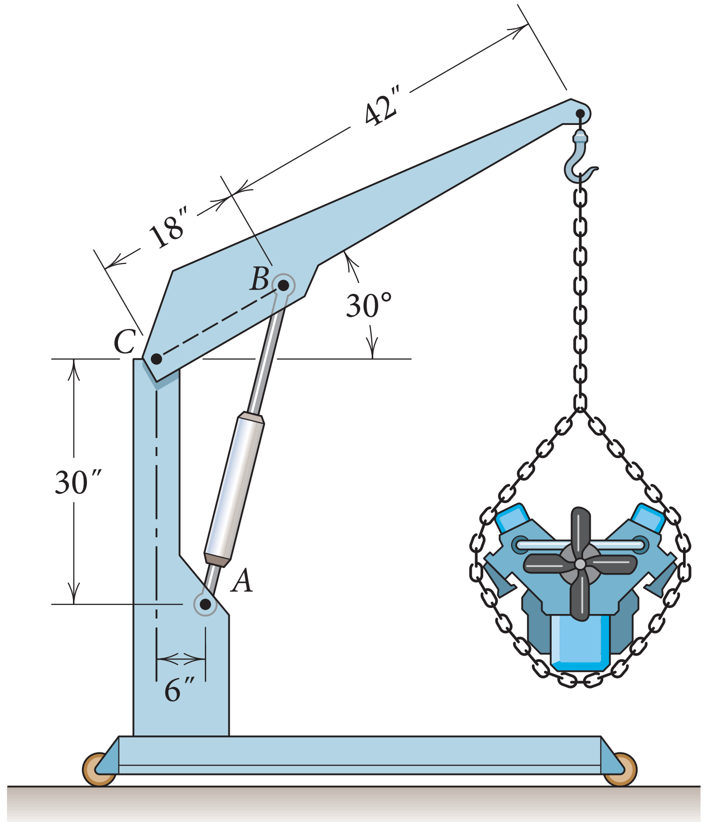


Figure 3

4. **Problem 4-17**

5. The uniform slender bar of length L is placed in the opening of width d at the 30° angle shown in Figure 5. For what range of L/d will the bar remain in static equilibrium? The coefficient of static friction at A and B is $\mu = 0.40$. (Answer: $2.37 \le L/d \le 8.14$)

6. Determine the maximum value of the angle θ for which the uniform slender rod will remain in equilibrium. The coefficient of static friction at A is $\mu = 0.80$, and friction associated with the small roller at B may be neglected. (Answer: $\theta = 6.29°$)

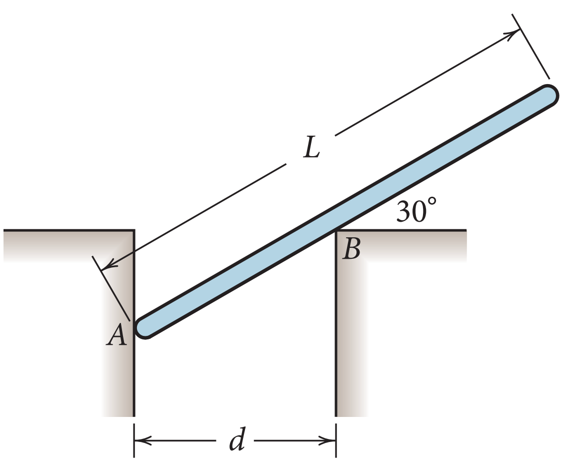


Figure 5

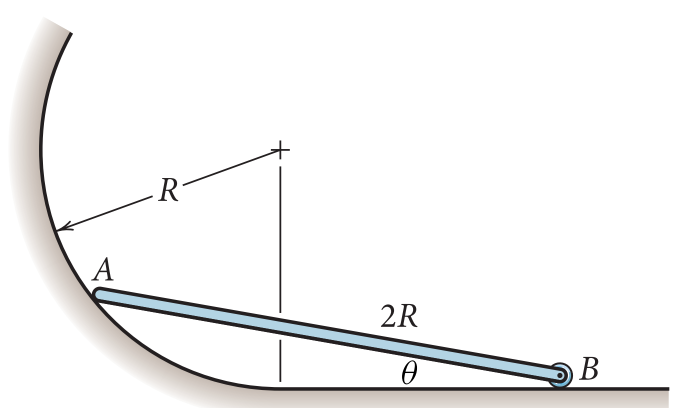


Figure 6

Assignment No. 2 Due: 6:00 p.m., Friday, January 25, 2019

The method of joints; the method of sections; frames and machines

Problems 5-13; 5-23, 5-30; 5-40, 5-48, 5-52

Assignment No. 3 Due: 6:00 p.m., Friday, February 1, 2019

Frames and machines;
Center of gravity and centroid for a body, composite bodies

Problems 5-46, 5-50, 5-51, 5-61; 6-11, 6-40

Assignment No. 4 Due: 6:00 p.m., Friday, February 8, 2019

Resultant of a distributed loading; moments of inertia for an area, moments of inertia for composite areas; Pressure

Unless otherwise stated, take the density of water to be $\rho_w = 1000$ kg/m^3 and its specific weight to be $\gamma_w = 62.4$ lb/ft^3. Also, assume all pressures are gage pressures.

Problems 3-115; 6-64, 6-88; 17-4, 17-41, 17-52

Assignment No. 5 Due: 6:00 p.m., Friday, February 15, 2019

Fluid Statics

Problems 17-65, 17-69, 17-80, 17-87, 17-104, 17-117

Reading Week: Monday, February 18 – Friday, February 22, 2019

Midterm Exam: 1:00 pm—2:50 pm, Tuesday, February 26, 2019

Assignment No. 6 Due: 6:00 p.m., Friday, March 8, 2019

Internal resultant loading; average normal stress in an axially loaded bar, average shear stress; allowable stress, design of simple connections

Problems 7-16; 7-36, 7-42, 7-43; 7-60, 7-68

Assignment No. 7 Due: 6:00 p.m., Friday, March 15, 2019

Deformation, strain; Poisson's ratio

Problems 7-74, 7-82, 7-83, 7-86; 8-21, 8-R5

Assignment No. 8 Due: 6:00 p.m., Friday, March 22, 2019

Axial deformation; Principle of superposition, statically indeterminate axially loaded member

Problems 9-4, 9-10, 9-22; 9-43, 9-47, 9-50

Assignment No. 9 Due: 6:00 p.m., Friday, March 29, 2019

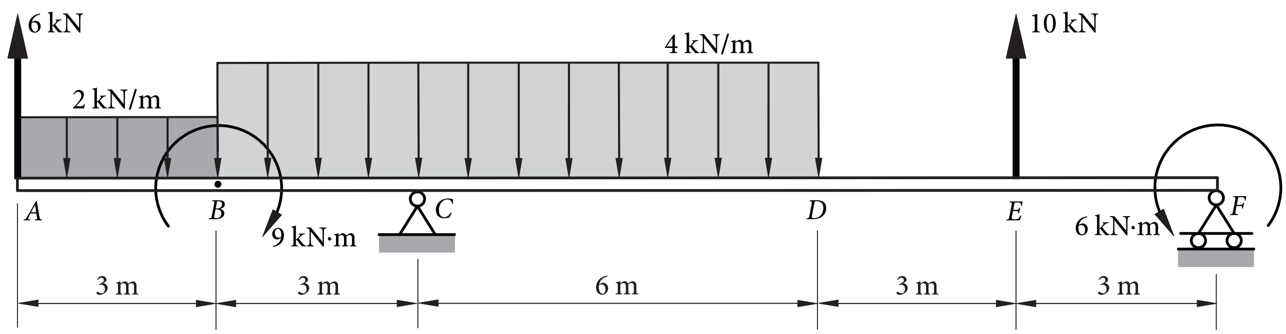
Thermal stress; Shear force and bending moment diagrams (Cut method)

Problems 9-58, 9-60, 9-64, 9-70, 9-71; 11-45

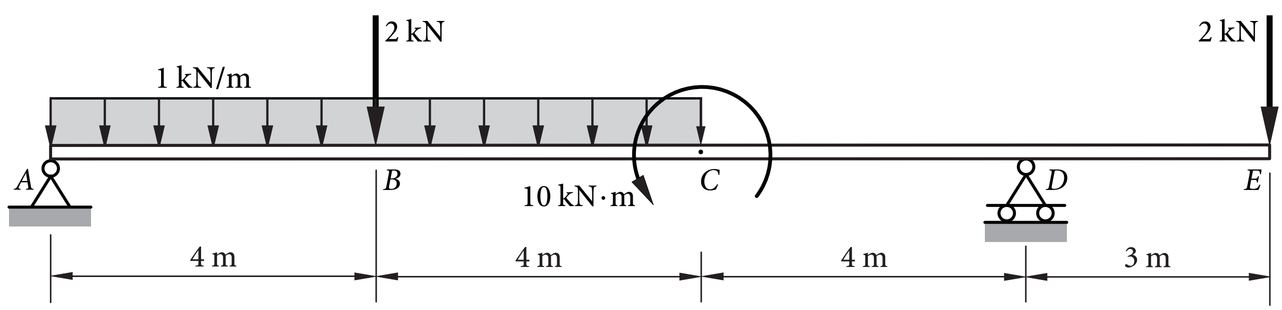
Assignment No. 10 Due: 6:00 p.m., Friday, April 5, 2019

Shear force and bending moment diagrams (short-cut method); bending stress

1. Draw the complete shear force and bending moment diagrams for the following loaded beam



2. Draw the complete shear force and bending moment diagrams for the following loaded beam



Problems 11-49, 11-79, 11-87, 11-101

Chapter 1: Equilibrium in 2-D

E1-1 If the combined moment of the two forces about point C is zero, determine

(1) the magnitude of the force P;

(2) the magnitude R of the resultant of the two forces;

(3) the coordinates x and y of the point A on the rim of the wheel about which the combined moment of the two forces is a maximum;

(4) the combined moment M_A of the two forces about A.

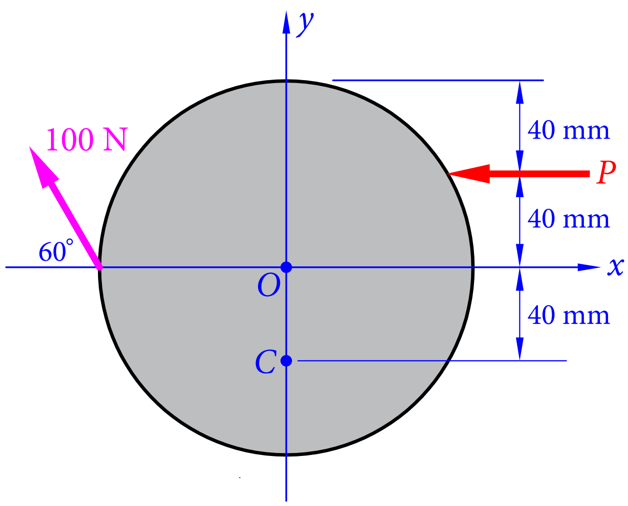


Figure E1-1

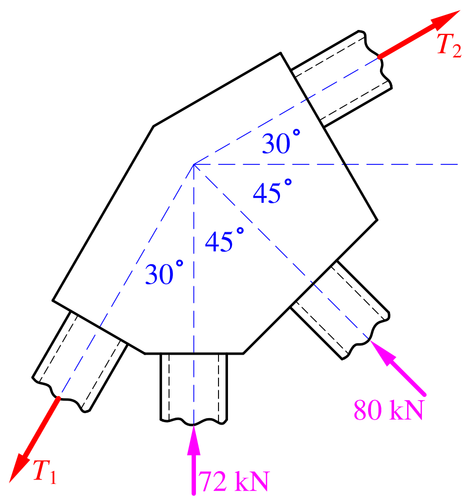


Figure E1-2

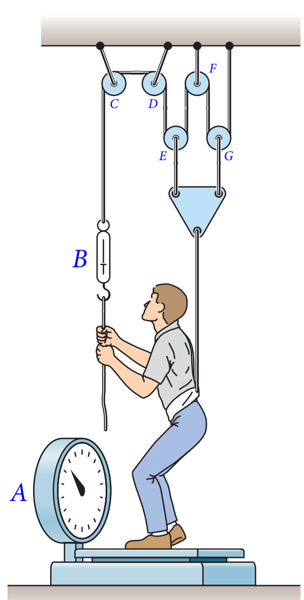


Figure E1-3

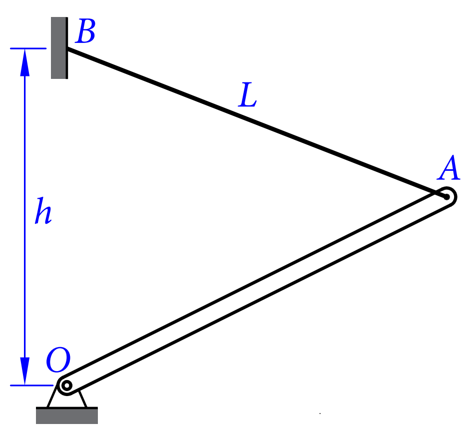


Figure E1-4

E1-2 The forces acting on four intersecting girders in a bridge truss are shown. Calculate T_1 and T_2.

E1-3 A civil engineering student wishes to weigh himself but has access only to a scale A with capacity limited to 400 N and a small 80-N spring dynamometer B. With the rig shown he discovers that when he exerts a pull on the rope so that B registers 76 N, the scale A reads 268 N. What is his correct weight W and mass m?

E1-4 The uniform beam OA of mass m is supported by the cable of length L. Show from the geometry of the force polygon and the figure that the cable tension is $T = mgL/(2h)$.

E1-5 For the following three cases, $F = 1000$ N, $AC = CB = CD = AD = L$, determine the reaction $\mathbf{R}_A$ at A on bar AB. Neglect the weight of the bars.

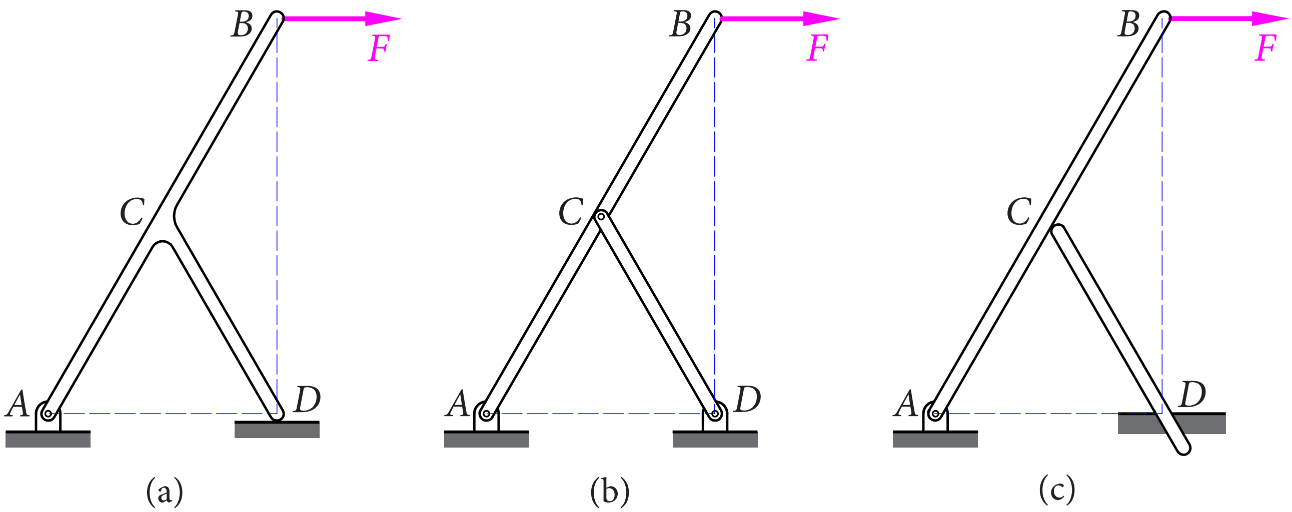


Figure E1-5

E1-6 For the two structures shown, determine the reaction at support B.

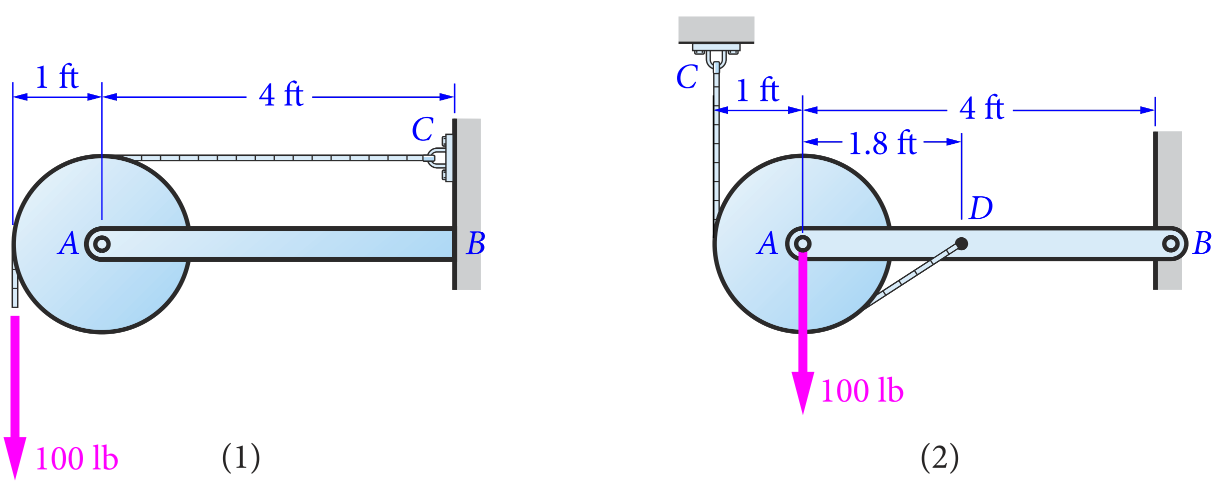


Figure E1-6

E1-7 The uniform 400-kg drum is mounted on a line of rollers at A and a line of rollers at B. An 80-kg man moves slowly a distance of 700 mm from the vertical centerline before the drum begins to rotate. All rollers are perfectly free to rotate, except one of them at B which must overcome appreciable friction in its bearing. Calculate the friction force F exerted by that one roller tangent to the drum and find the magnitude R of the force exerted by all rollers at A on the drum for this condition.

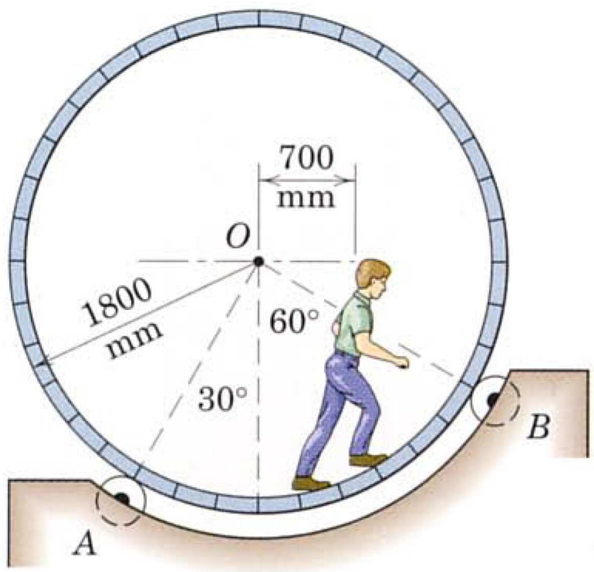


Figure E1-7

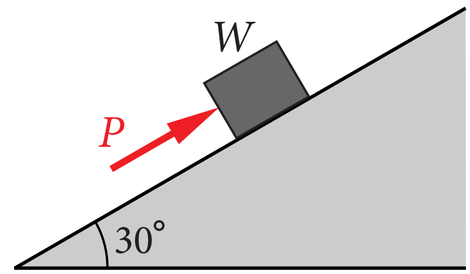


Figure E1-8

E1-8 Consider a weight $W = 200$ N on a slope. The coefficient of friction between the weight and slope is $\mu_s = 0.2$. Determine the values of force P that will cause motion (a) up the slope, (b) down the slope.

E1-9 Two weights $W_A = 400$ N and $W_B = 200$ N are connected by a rod AB of length l. A vertical force of 100 N is applied at the midpoint of AB. The coefficient of friction between the weights and surfaces is $\mu_s = 0.3$. Determine the value of force P that will start the system moving to the right.

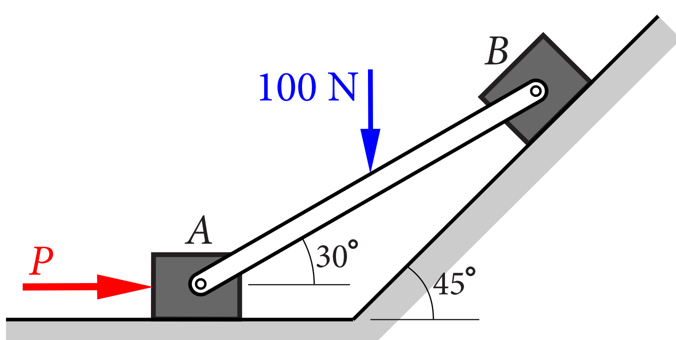


Figure E1-9

Chapter 2: Structural Analysis

E2-1 The equiangular truss is loaded and supported as shown. Determine the forces in all members in terms of the horizontal load P.

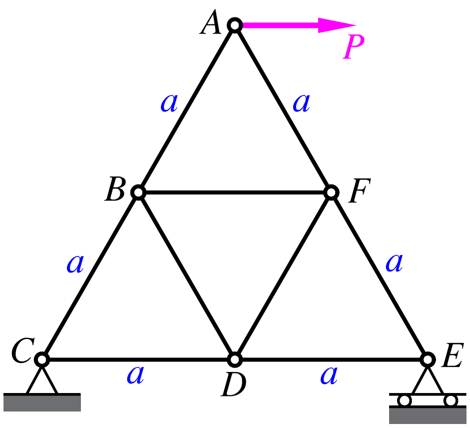


Figure E2-1

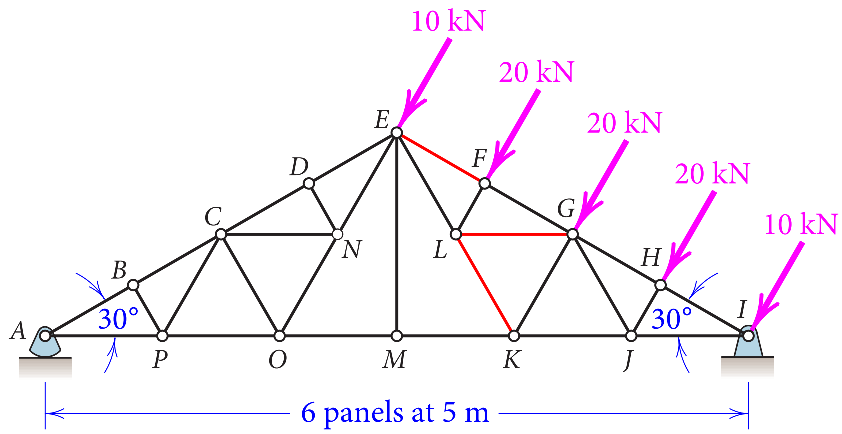


Figure E2-2

E2-2 Find the forces in members EF, KL, and GL for the Fink truss shown. The angles are 30°, 60°, or 90°.

E2-3 Calculate the forces in members CB, CG, and BG for the loaded truss with $W = 20$ kN.

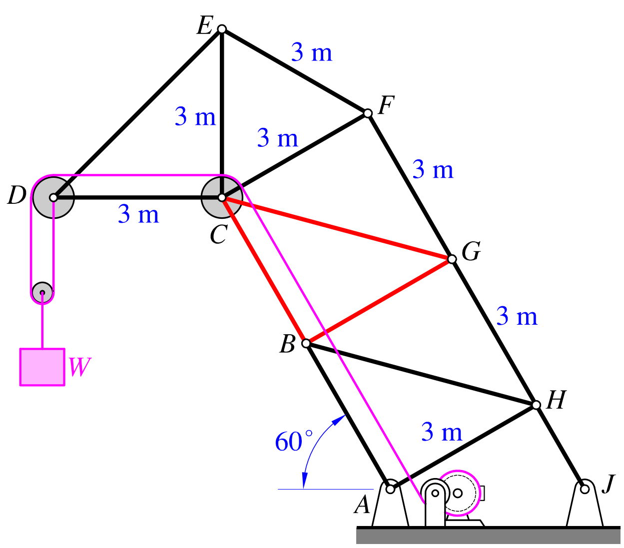


Figure E2-3

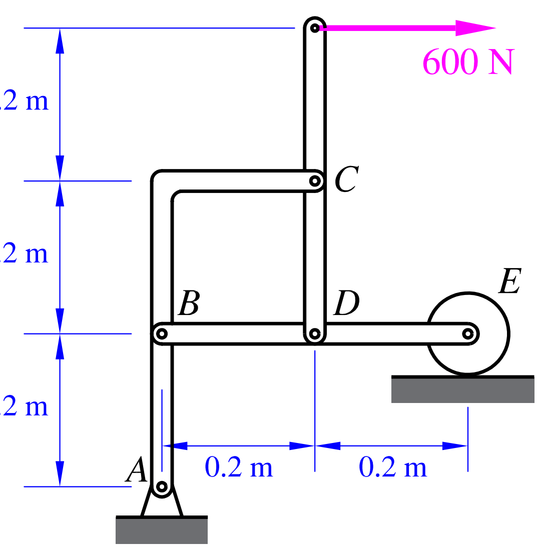


Figure E2-4

E2-4 Determine the force supported by the pin at C for the loaded frame.

E2-5 The retractable shelf is maintained in the position shown by two identical linkage-and-spring systems; only one of the systems is shown in the figure. A 20-kg machine is placed on the shelf so that half of its weight is supported by the system shown. Neglect the weights of the shelf and the linkages. Determine the force in link AB and the tension in the spring.

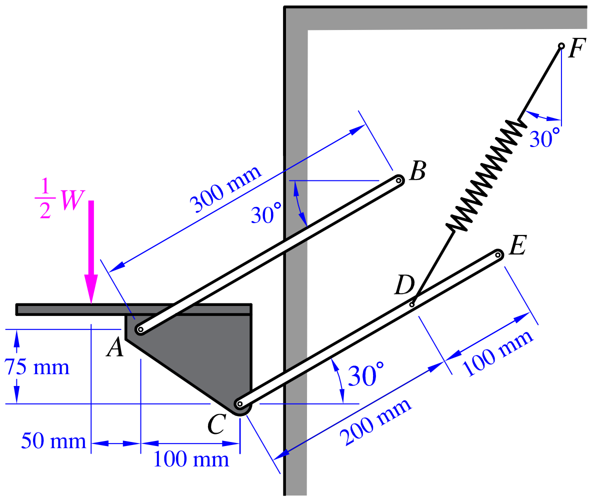


Figure E2-5

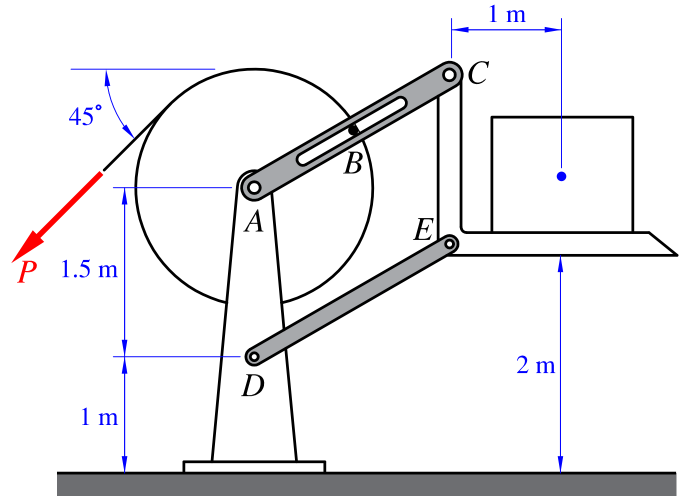


Figure E2-6

E2-6 The mechanism shown is designed to keep its load level while raising it ($CE = 1.5$ m). A pin on the rim of the 2-m diameter pulley fits in a slot on arm *ABC*. Arms *ABC* and *DE* are each 2 m long, and the package being lifted weighs 1 kN. The mechanism is raised by pulling on the rope that is wrapped around the smooth pulley. Neglect the weight of each member of the mechanism. Determine the forces acting on member *CE* at joint *C* when the package has been lifted 2 m as shown, the force acting on pin *B*, and the force *P* applied to the rope.

Chapter 3: Geometric Properties and Distributed Forces

E3-1 Locate the centroid of the area shown in the figure by direct integration.

E3-2 Find the coordinates of the center of mass of the bracket, made from a plate of uniform thickness.

E3-3 As part of a preliminary design study, the effects of wind loads on a 300-m building are investigated. For the parabolic distribution of wind pressure shown in Figure E3-3, compute the force and moment reactions at the base *A* of the building due to the wind load. The depth of the building is 60 m.

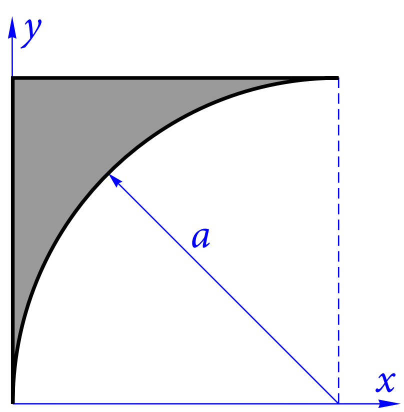


Figure E3-1

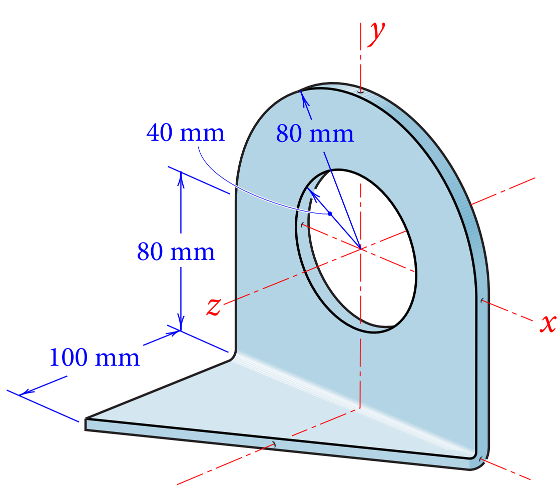


Figure E3-2

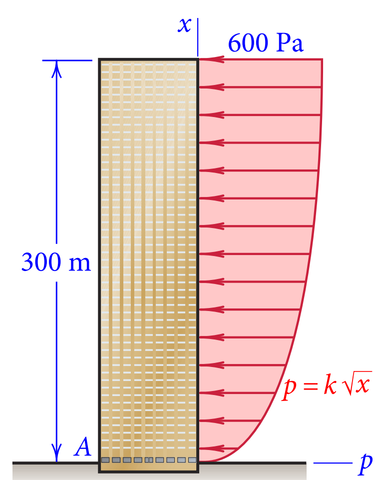


Figure E3-3

E3-4 Determine the moments of inertia of the area about the x-axis.

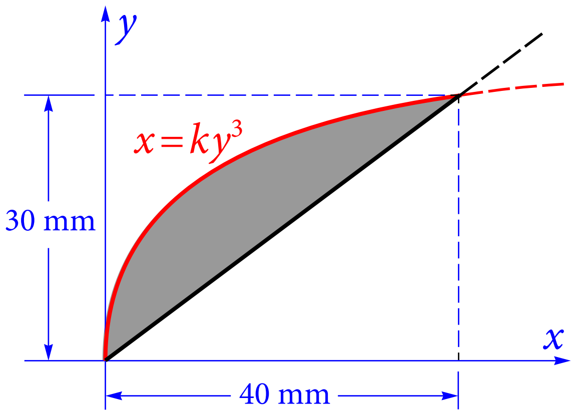


Figure E3-4

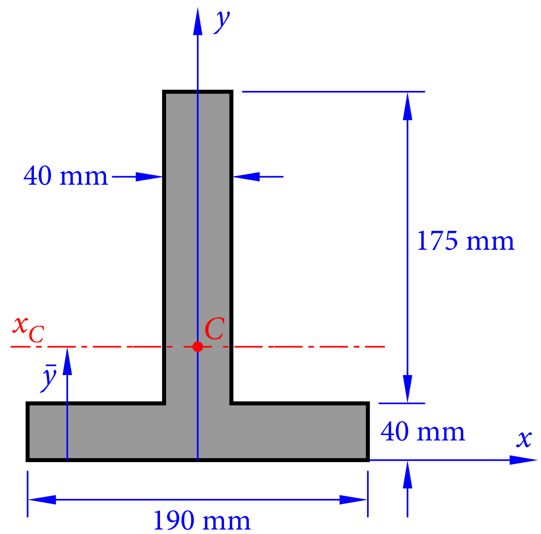


Figure E3-5

E3-5 Find the moment of inertia of the T-section about the centroidal axis x_C.

E3-6 For the semicircular area as shown in Figure (a), it is given that the second moment of area about the x-axis and the y-coordinate of the centroid are

$$I_x = \frac{1}{8}\pi r^4, \qquad \bar{y} = \frac{4r}{3\pi}.$$

For the triangular area as shown in Figure (b), it is known that the second moment of area about the x-axis and the y-coordinate of the centroid are

$$I_x = \frac{1}{12}bh^3, \qquad \bar{y} = \frac{1}{3}h.$$

Determine the second moment of area I_x of the shaded area, as shown in Figure (c), about the x-axis.

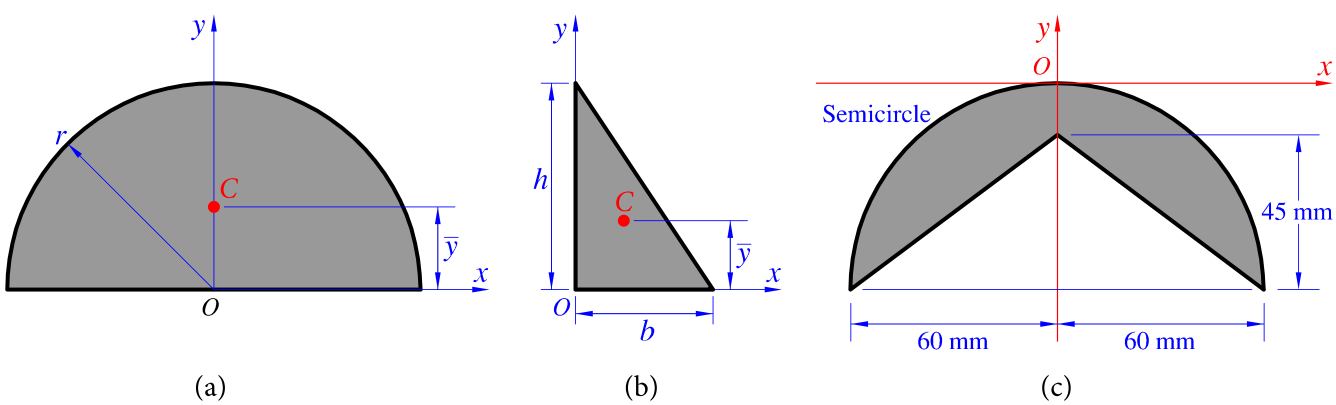


Figure E3-6

Chapter 4: Fluid Statics

Unless otherwise stated, take the density of water to be $W = 1000\,\text{kg/m}^3$ and its specific weight to be $W = 62.4\,\text{lb/ft}^3$. Also, assume all pressures are gage pressures.

E4-1 Because of a leak in a buried gasoline storage tank, water has seeped in to the depth shown in Figure E4-1. The specific weight of the gasoline is $\gamma_{\text{gasoline}} = 42.4$ lb/ft^3. Determine the pressure at the gasoline–water interface and at the bottom of the tank. Express the pressure in units of lb/ft^2, lb/in^2, and as a pressure head in feet of water.

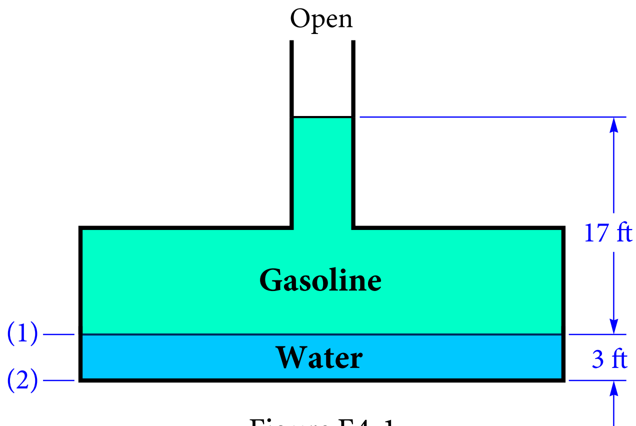


Figure E4-1

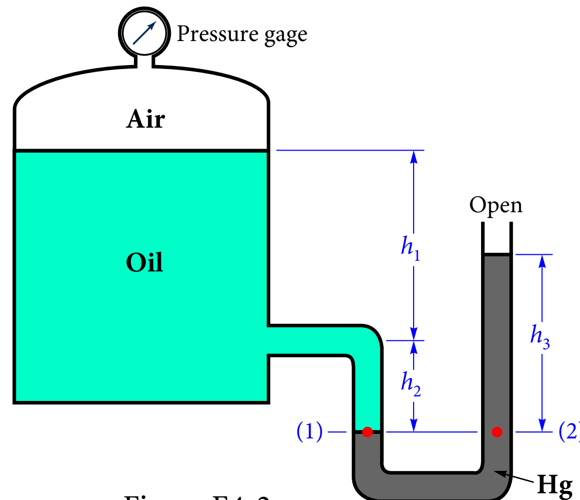


Figure E4-2

E4-2 A closed tank contains compressed air and oil as is shown in Figure E4-2. An U-tube manometer using mercury is connected to the tank as shown. The column heights are $h_1 = 36$ in, $h_2 = 6$ in, and $h_3 = 9$ in. Take $\gamma_{\text{oil}} = 56.2$ lb/ft^3 and $\gamma_{\text{Hg}} = 848.6$ lb/ft^3. Determine the pressure reading (in psi) of the gage.

E4-3 The air space in the closed fresh-water tank is maintained at a pressure of $0.80\,\text{lb/in}^2$ (above atmospheric). Determine the resultant force R exerted by the air and water on the end of the tank.

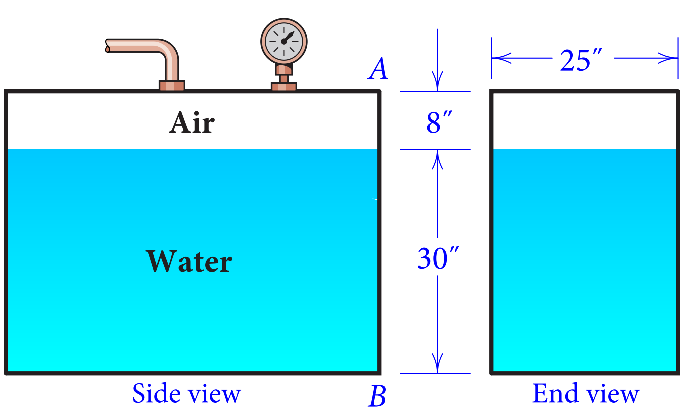


Figure E4-3

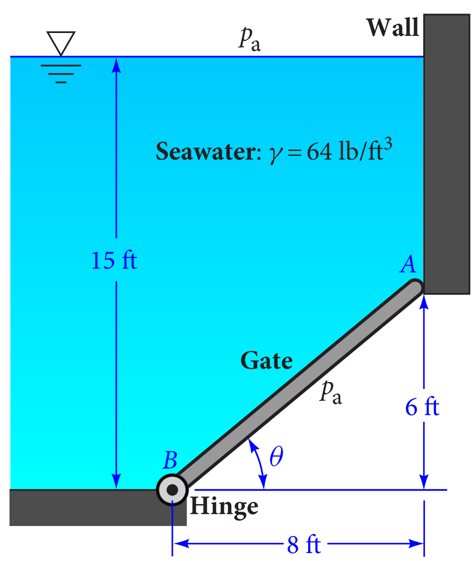


Figure E4-4

E4-4 The gate in Figure E4-4 is 5 ft wide, is hinged at point B, and rests against a smooth wall at point A. Compute

(1) the force on the gate due to seawater pressure,

(2) the force exerted by the wall at point A and the reaction force at hinge B.

E4-5 A trapezoidal opening in the vertical wall of a tank is closed by a flat plate which is hinged at its upper edge. The plate is symmetrical about its centreline and is 1.5 m deep. Its upper edge is 2.7 m long and its lower edge is 1.2 m long. The free surface of the water in the tank stands 1.1 m above the upper edge of the plate. Calculate the moment about the hinge line required to keep the plate closed.

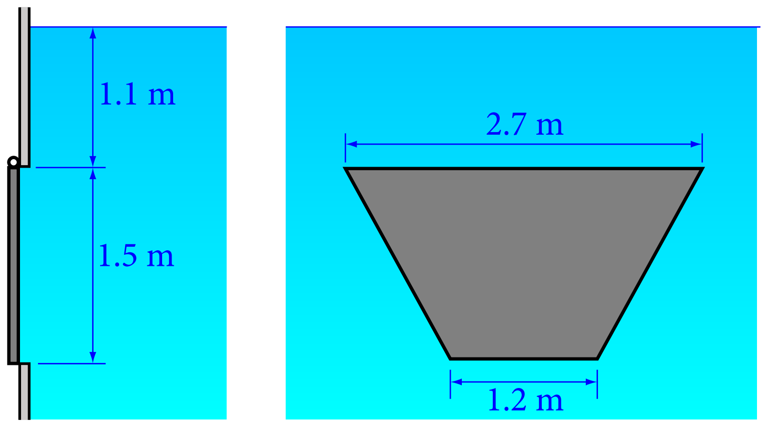


Figure E4-5

E4-6 The angle between a pair of lock gates is 140° and each gate is 6 m high and 1.8 m wide, supported on hinges 0.6 m from the top and bottom of the gate. If the depths of water on the upstream and downstream sides are 5 m and 1.5 m, respectively, determine the reactions at the top and bottom hinges. The density of water is $\rho = 1000$ kg/m^3.

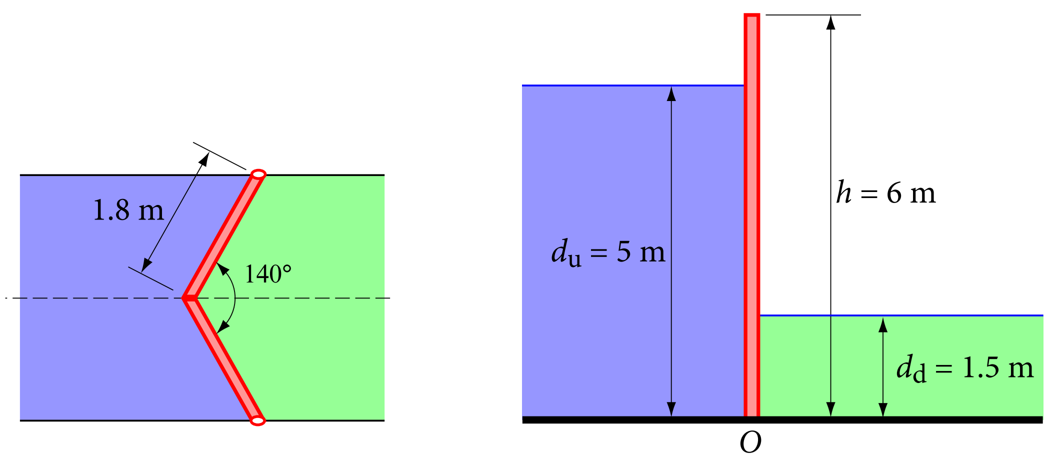
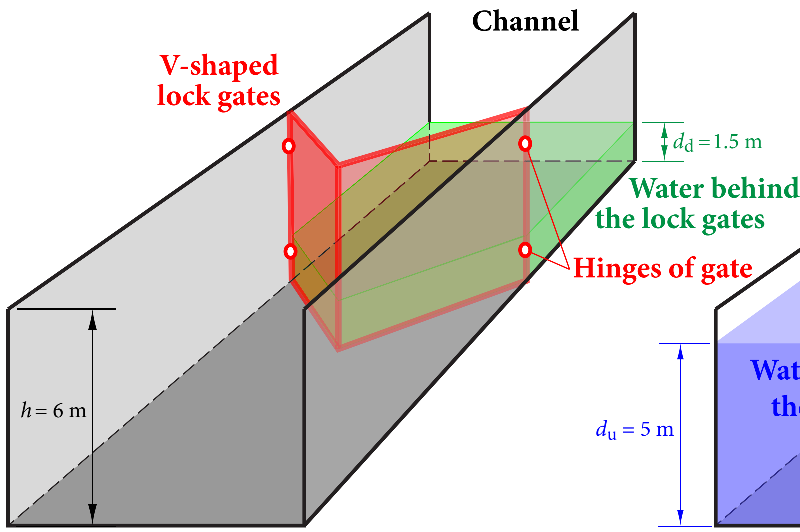


Figure E4-6



E4-7 The curved and flat plates are pin connected at A, B, and C. They are submerged in water at the depth shown. Determine the horizontal and vertical components of reaction at pin B. The plates have a width of 4 m.

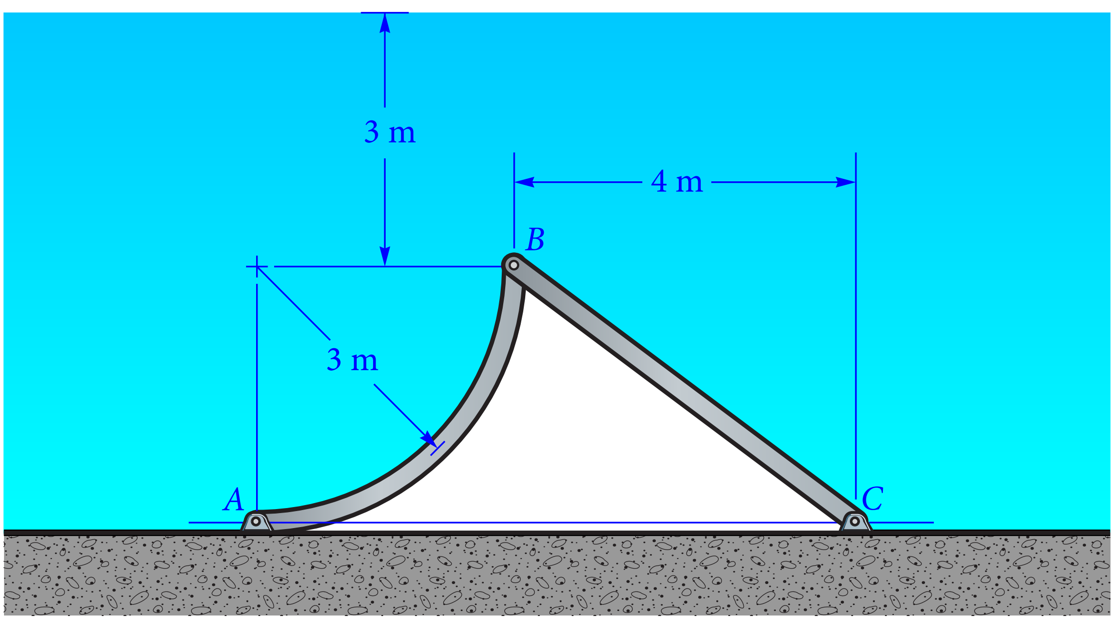


Figure E4-7

Chapter 5: Stress and Strain

E5-1 For the loaded frame, find the internal forces at section 1.

E5-2 The 50-lb lamp is supported by three steel rods connected together by a ring at A. Determine which rod is subjected to the greatest normal stress and compute its value. The diameter of the rods are $d_{AB} = 0.35$ in, $d_{AC} = 0.25$ in, $d_{AD} = 0.3$ in.

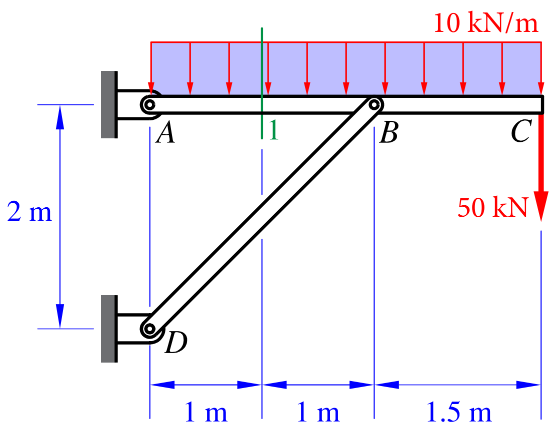


Figure E5-1

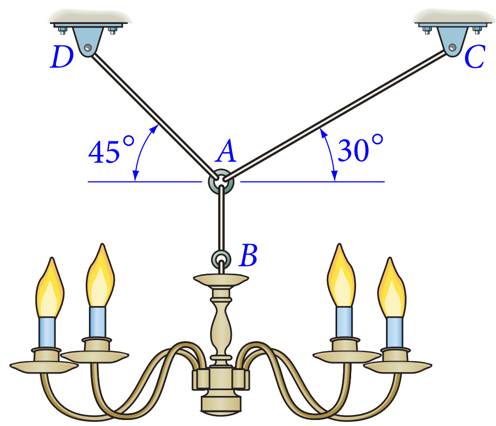


Figure E5-2

E5-3 A semicircular bracket assembly is used to support a steel staircase in an office building. One design under consideration, referred to as the eccentric design, uses two separate L-shaped brackets, each having a clevis attached to a steel hanger rod to support the staircase. Photos of the bracket attachment and hanger rod in the eccentric design are shown below.

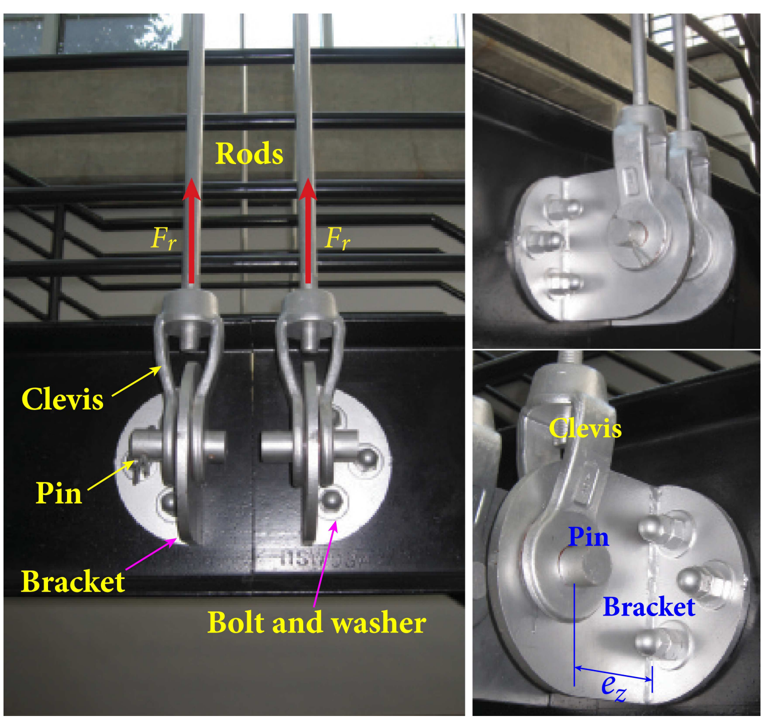


Figure E5-3(a)

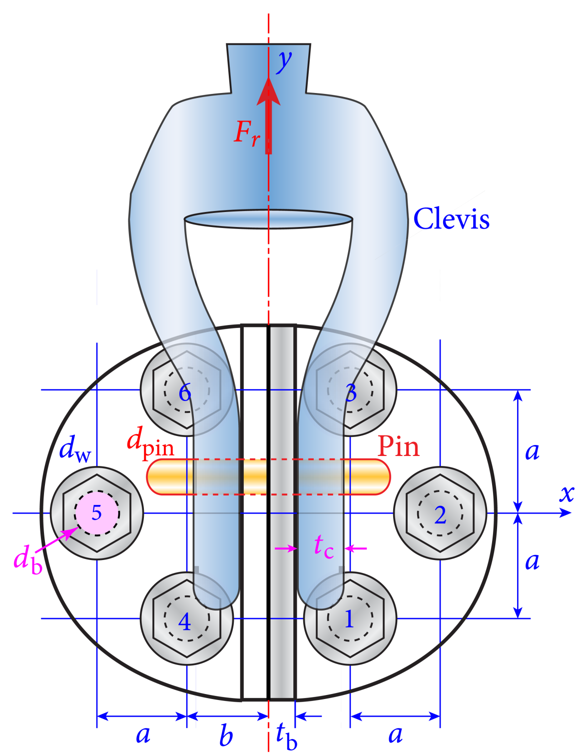


Figure E5-3(b)

The design engineer would like to also consider a symmetric bracket design. The symmetric design uses a single hanger rod attached by a clevis and pin to a T-shaped bracket in which the two separate L-brackets are attached along a vertical axis (Figure E5-3(b)). In this design, the eccentric moment of the rod force about the z axis is eliminated. In the symmetric design, the weight of the staircase and the connection itself, and any building occupants who are using the staircase, is estimated to result in a force of $F_r = 9600$ N in the single hanger rod.

Determine the following stresses in the symmetric connection:

(a) Average in-plane shear stress in bolts 1 to 6.

(b) Bearing stress between the clevis pin and the bracket.

(c) Bearing stress between the clevis and the pin.

(d) Bolt forces in the z-direction at bolts 1 and 4 due to moment about the x-axis, and resulting normal stress in bolts 1 and 4.

(e) Bearing stress between the bracket and washer at bolts 1 and 4.

(f) Shear stress through the bracket at bolts 1 and 4.

Use the dimensions

$$a = 50 \text{ mm}, \quad b = 40 \text{ mm}, \quad d_{\text{w}} = 40 \text{ mm}, \quad d_{\text{b}} = 18 \text{ mm}, \quad d_{\text{pin}} = 38 \text{ mm},$$
$$t_{\text{b}} = 12 \text{ mm}, \quad t_{\text{c}} = 14 \text{ mm}, \quad e_z = 150 \text{ mm}.$$

E5-4 The rod BC is made of steel having an allowable tensile stress $(\sigma_t)_{\text{allow}} = 155$ MPa. The allowable bearing stress for the wood is $(\sigma_b)_{\text{allow}} = 28$ MPa. The beam is assumed to be pin-connected at A. Determine the required diameter of the bolt and the required outer diameter of the washer so that it can support the load shown. Assume that the hole in the washer is the same size as the bolt diameter.

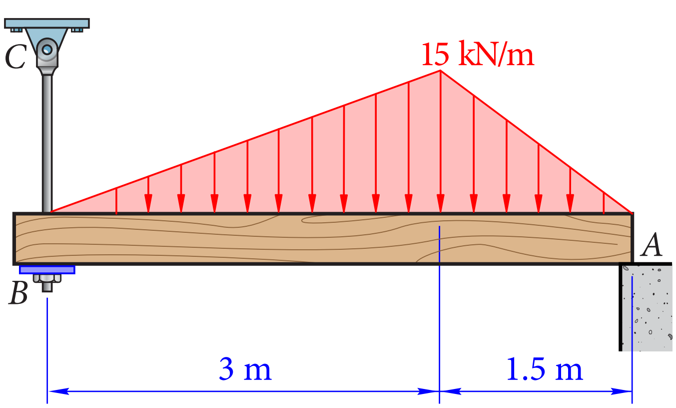


Figure E5-4

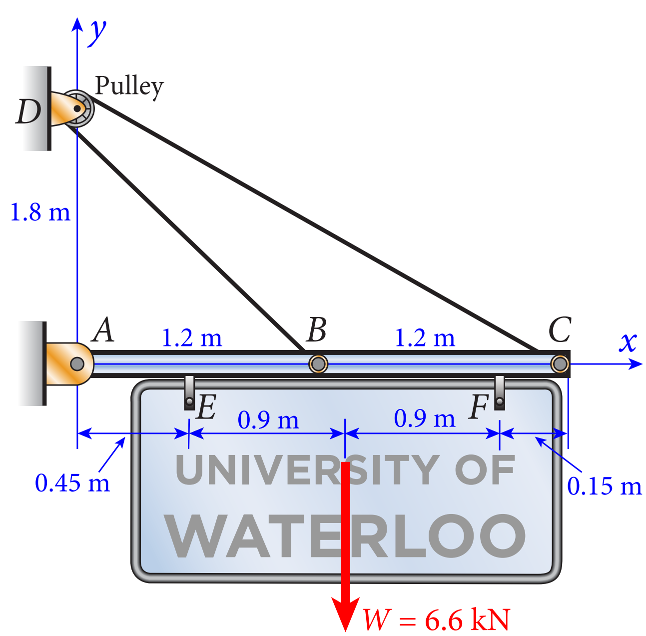


Figure E5-5

E5-5 The cable-pipe structure *ABCD* has pin supports at points *A* and *D*, which are 1.8 m apart. Member *ABC* is a steel pipe, and member *BDC* is a continuous cable which passes over a frictionless pulley at *D*. A sign weighing 6.6 kN is suspended from bar *ABC* at points *E* and *F*. Determine the required diameter of the pins at *A*, *B*, *C*, and *D* if the allowable stress in shear is 45 MPa. Also, find the required cross-sectional areas of cable *BDC* if the allowable stress in tension is 124 MPa.

☞ The pins at the supports are in double shear. Also, consider only the weight of the sign; disregard the weights of members *BDC* and *ABC*.

E5-6 When the rigid rod *AB* is horizontal, cable *BC* is strain free.

(1) Determine an expression for the average extensional strain in rod *BC* as a function of the angle θ of clockwise rotation of *AB* in the range $0 \leqslant \theta \leqslant \pi/2$.

(2) Find an approximation for $\varepsilon(\theta)$ that gives acceptable accuracy for values of θ when $\theta \ll 1$ rad.

E5-7 An initially rectangular element of material is deformed as shown (note that the deformation is greatly exaggerated). Calculate the normal strains ε_x and ε_y, and the shear strain γ for the element.

E5-8 A hollow plastic circular pipe (length L_p, inner diameter d_1, and outer diameter d_2) is inserted as a liner inside a cast iron pipe (length L_c, inner diameter d_3, and outer diameter d_4).

(1) Derive a formula for the required initial length L_p of the plastic pipe so that when it is compressed by some force P, the final length of both pipes is the same and also, at the same time, the final outer diameter of the plastic pipe is equal to the inner diameter of the cast iron pipe.

(2) Using $L_c = 0.25$ m, $E_c = 170$ GPa, $E_p = 2.1$ GPa, $\nu_c = 0.3$, $\nu_p = 0.4$,

$$d_1 = 109.8 \text{ mm}, \quad d_2 = 110 \text{ mm}, \quad d_3 = 110.2 \text{ mm}, \quad d_4 = 115 \text{ mm},$$

find the initial length L_p (m) and the final thickness t_p (mm) for the plastic pipe.

(3) What is the required compressive force P (N)? What are the final normal stresses (MPa) in both pipes?

(4) Compare initial and final volumes (mm^3) for the plastic pipe.

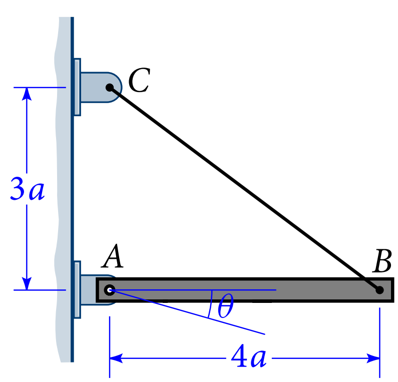


Figure E5-6

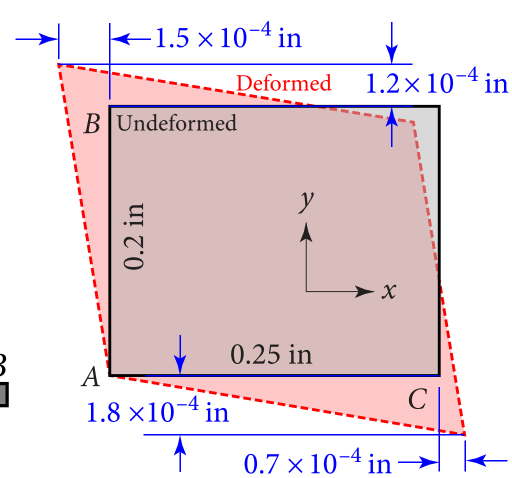


Figure E5-7

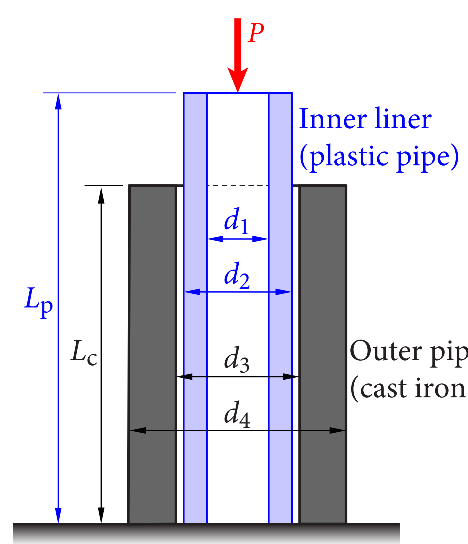


Figure E5-8

Chapter 6: Axial Loading

E6-1 The steel column is used to support the symmetric loads from the two floors of a building. Determine the vertical displacement of its top A if the column has a cross-sectional area of 23.4 in^2. $E_{\text{steel}} = 29 \times 10^3$ ksi.

E6-2 The steel pipe is filled with concrete and subjected to a compressive force of 80 kN. Determine the stress in the concrete and the steel due to this loading. The pipe has an outer diameter of 80 mm and an inner diameter of 70 mm. $E_{\text{steel}} = 200$ GPa, $E_{\text{concrete}} = 24$ GPa.

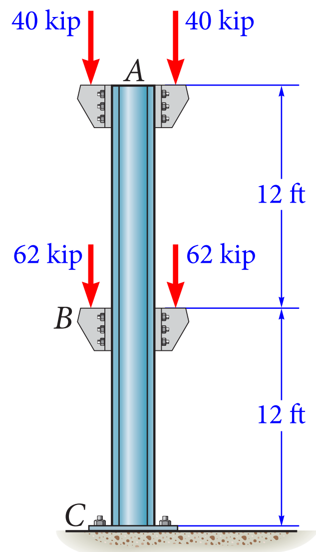


Figure E6-1

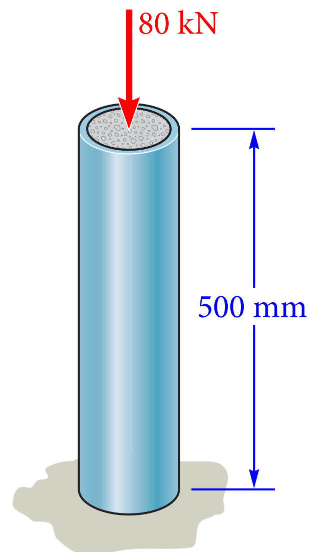


Figure E6-2

E6-3 The steel pipe has an outer radius of 20 mm and an inner radius of 15 mm. If it fits snugly between the fixed walls before it is loaded, determine the reaction at the walls when it is subjected to the load shown. $E_{\text{steel}} = 200$ GPa.

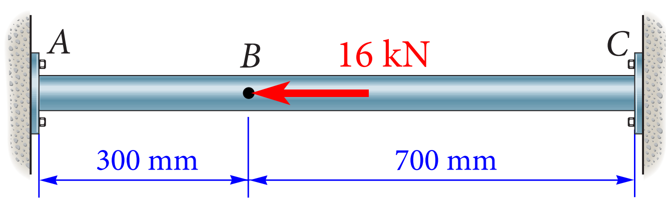


Figure E6-3

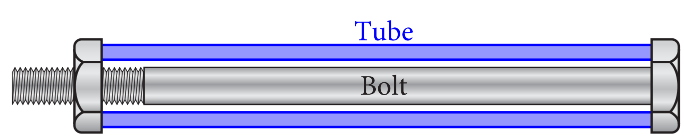


Figure E6-4

E6-4 The assembly consists of a steel bolt and a brass tube. If the nut is drawn up snug against the tube so that $L = 75$ mm, then turned an additional amount so that it advances 2 mm on the bolt, determine the force in the bolt and the tube. The bolt has a diameter of 7 mm and the tube has a cross-sectional area of 100 mm^2. $E_{\text{steel}} = 200$ GPa, $E_{\text{brass}} = 100$ GPa.

E6-5 A sleeve in the form of a circular tube of length L is placed around a bolt and fitted between washers at each end. The nut is then turned until it is just snug. The sleeve and bolt are made of different materials and have different cross-sectional area. Assume that the coefficient of thermal expansion α_s of the sleeve is greater than the coefficient α_b of the bolt.

(1) If the temperature of the entire assembly is raised by an amount ΔT, what stresses σ_s and σ_b are developed in the sleeve and bolt, respectively?

(2) What is the increase δ in the length L of the sleeve and bolt?

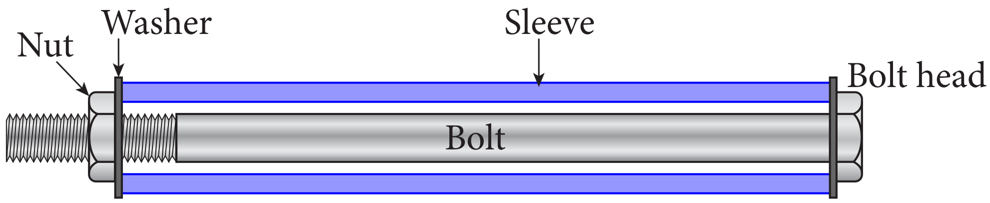


Figure E6-5

E6-6 A copper bar AB of length 0.635 m and diameter 50 mm is placed in position at room temperature with a gap of 0.2 mm between end A and a rigid restraint as shown. The bar is supported at end B by an elastic spring with spring constant $k = 210 \times 10^6$ N/m. Neglect gravity effects. For copper, $E = 100$ GPa and $\alpha = 17.5 \times 10^{-6}/°C$.

(1) Find the axial compressive stress σ_c in the bar if the temperature *of the bar only* rises by 27°C.

(2) What is the compression (shortening) of the spring?

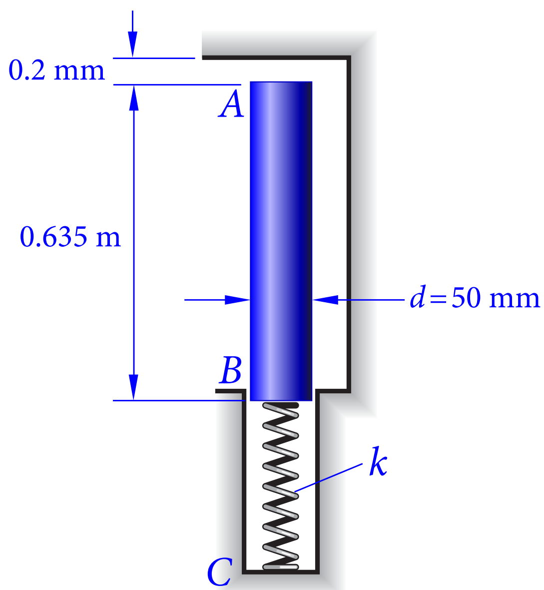


Figure E6-6

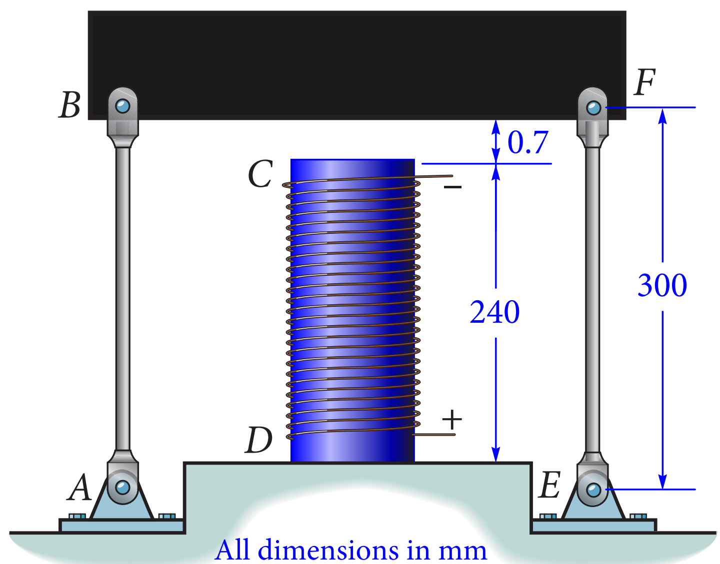


Figure E6-7

E6-7 The center rod CD of the assembly is heated from $T_1 = 30°C$ to $T_2 = 180°C$ using electrical resistance heating. Also, the two end rods AB and EF are heated from $T_1 = 30°C$ to $T_2 = 50°C$. At the lower temperature T_1 the gap between C and the rigid bar is 0.7 mm. Determine the force in rods AB and EF caused by the increase in temperature. Rods AB and EF are made of steel, and each has a cross-sectional area of 125 mm^2. CD is made of aluminum and has a cross-sectional area of 375 mm^2. $E_{steel} = 200$ GPa, $E_{aluminum} = 70$ GPa, $\alpha_{steel} = 12 \times 10^{-6}/°C$, and $\alpha_{aluminum} = 23 \times 10^{-6}/°C$.

Chapter 7: Bending

E7-1 For the simply supported beam, draw the shear force and bending moment diagrams.

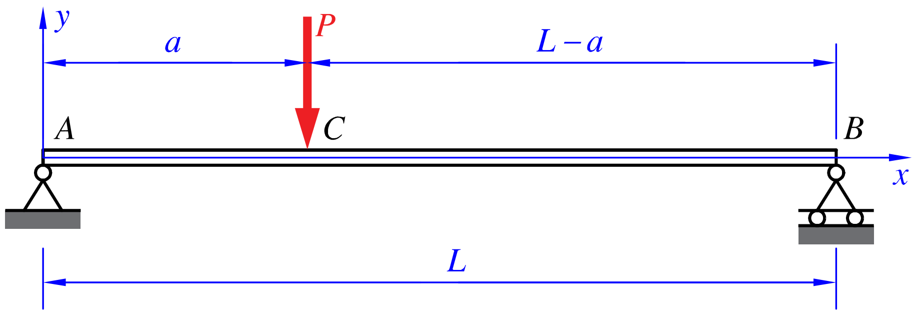


Figure E7-1

E7-2 For the cantilever beam carrying uniformly distributed load as shown, draw the shear force and bending moment diagrams.

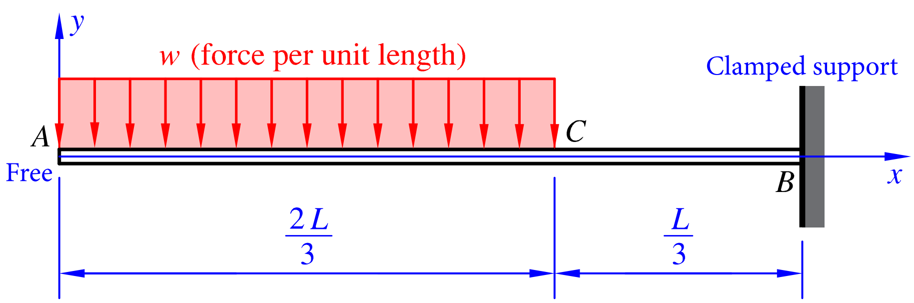


Figure E7-2

E7-3 Draw the complete shear force and bending moment diagrams for the following loaded beam.

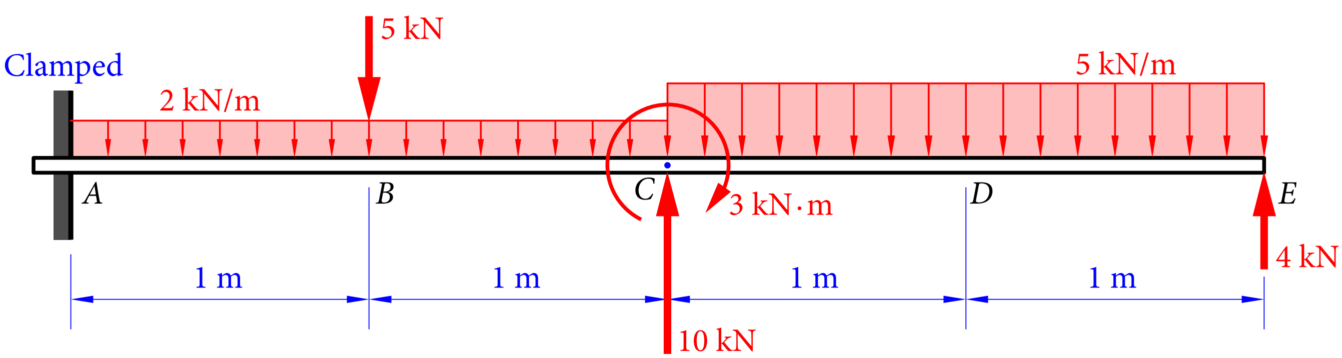


Figure E7-3

E7-4 The aluminum beam, with a cross-sectional area in the form of a cross, is subjected to loading as shown. Determine the maximum bending stresses.

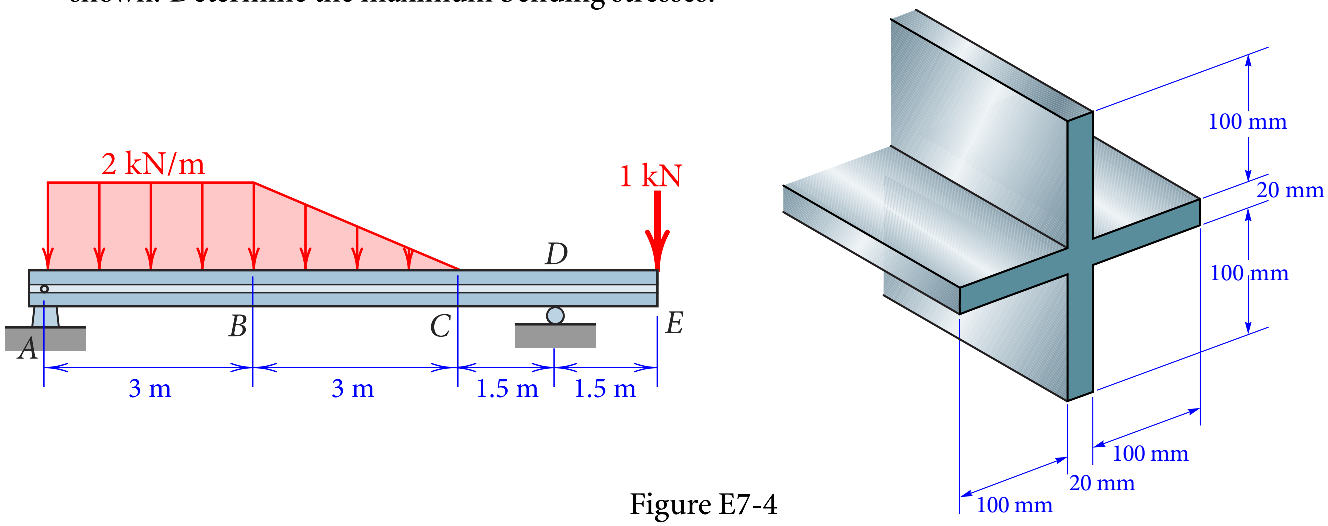


Figure E7-4

E7-5 For the semicircular area shown in Figure (a), it is given that the y-coordinate of the centroid and the moment of inertia about the centroidal axis $\bar{x}$ are, respectively,

$$\bar{y} = \frac{4r}{3\pi}, \qquad \bar{I}_x = r^4\left(\frac{\pi}{8} - \frac{8}{9\pi}\right).$$

A cantilever steel beam AB with cross-section as shown in Figure (b) is subjected to a triangularly distributed load as shown in Figure (c).

(1) Determine the bending moment at support A.

(2) Determine the coordinate $\bar{y}$ of the centroid C.

(3) Find the moment of inertia I about the neutral axis.

(4) Find the maximum tensile and compressive stresses at section A.

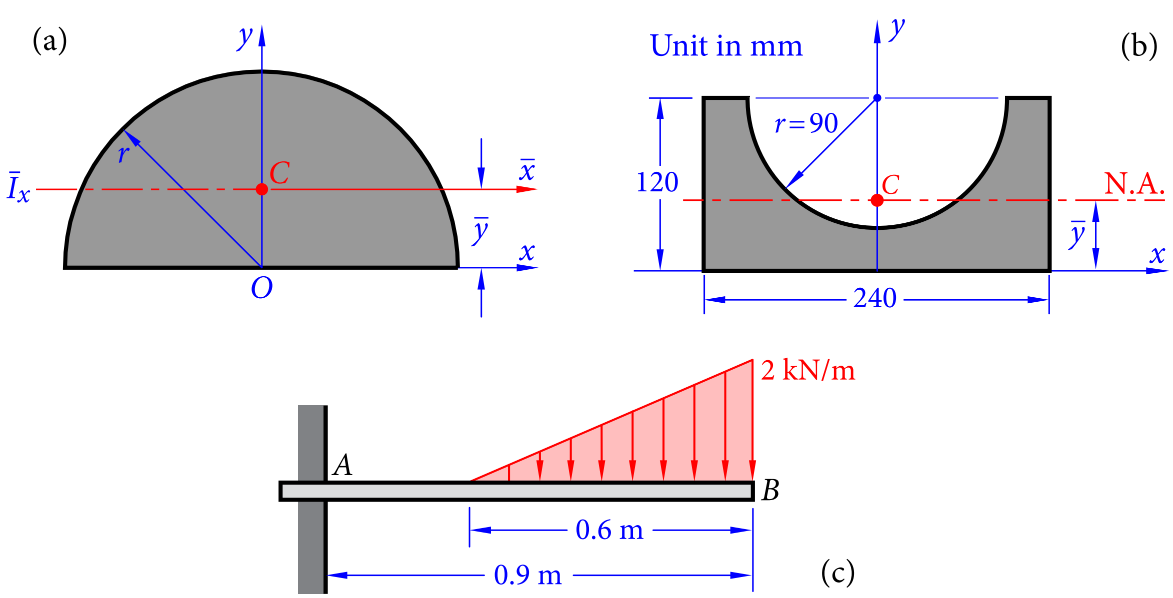


Figure E7-5