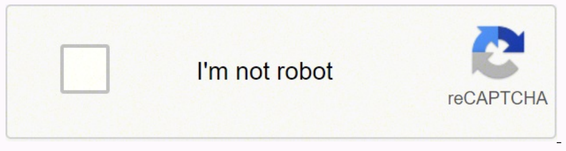

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Mechanics of materials 7th edition beer johnston solution

CHAPTER 2 PROBLEM 2.1 A nylon thread is subjected to a 8.5-N tension force. Knowing that E 3.3 GPa and that the length of the thread increases by 1.1%, determine (a) the diameter of the thread, (b) the stress in the thread. SOLUTION (a) 1.1 0.011 100 Stress: E (3.3 109)(0.011) 36.3 106 Pa (b) Strain: Area: A Diameter: d L P A P 4A 8.5
234.16 109 m 2 36.3 106 (4)(234.16 109) 546 106 m d 0.546 mm 36.3 MPa Stress: PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded,
distributed, or posted on a website, in whole or part. 93 PROBLEM 2.2 A 4.8-ft-long steel wire of 14 -in.-diameter is subjected to a 750-lb tensile load. Knowing that E = 29 × 106 psi, determine (a) the elongation of the wire, (b) the corresponding normal stress. SOLUTION (a) Deformation: Area: A PL ; AE A (0.25 in.)2 4 d2 4 4.9087 10 2 in 2 (750
lb)(4.8 ft 12 in./ft) (4.9087 102 in 2)(29 106 psi) 3.0347 10 2 in. (b) Stress: Area: P A (750lb) (4.9087 102 in 2) 0.0303 in. 1.52790 10 4 psi 15.28 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner.
This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 94 PROBLEM 2.3 An 18-m-long steel wire of 5-mm diameter is to be used in the manufacture of a prestressed concrete beam. It is observed that the wire stretches 45 mm when a tensile force P is applied. Knowing that E 200 GPa,
determine (a) the magnitude of the force P, (b) the corresponding normal stress in the wire. SOLUTION (a) PL , or AE P AE L 1 1 with A d 2 (0.005)2 19.6350 106 m 2 4 4 P (0.045 m)(19.6350 106 m 2)(200 109 N/m 2) 9817.5 N 18 m P 9.82 kN (b) P A 9817.5 N 19.6350 10 6 6 m 2 500 MPa 500 10 Pa PROPRIETARY MATERIAL.
Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 95 PROBLEM 2.4 Two gage marks are placed exactly 250 mm apart
on a 12-mm-diameter aluminum rod with E = 73 GPa and an ultimate strength of 140 MPa. Knowing that the distance between the gage marks is 250.28 mm after a load is applied, determine (a) the stress in the rod, (b) the factor of safety. SOLUTION (a) L L0 250.28 mm 250 mm 0.28 mm L0 0.28 mm 250 mm 1.11643 10 4 E (73 109 Pa)
(1.11643 10 4) 8.1760 107 Pa 81.8 MPa (b) F.S. u 140 MPa 81.760 MPa 1.71233 F.S. 1.712 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated,
forwarded, distributed, or posted on a website, in whole or part. 96 PROBLEM 2.5 An aluminum pipe must not stretch more than 0.05 in. when it is subjected to a tensile load. Knowing that E 10.1 106 psi and that the maximum allowable normal stress is 14 ksi, determine (a) the maximum allowable length of the pipe, (b) the required area of the pipe
if the tensile load is 127.5 kips. SOLUTION (a) PL AE Thus, L EA E (10.1 106) (0.05) P 14 103 L 36.1 in. (b) P A Thus, A P 127.5 103 14 103 A 9.11 in 2 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner.
This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 97 PROBLEM 2.6 A control rod made of yellow brass must not stretch more than 3 mm when the tension in the wire is 4 kN. Knowing that E = 105 GPa and that the maximum allowable normal stress is 180 MPa, determine (a) the
smallest diameter rod that should be used, (b) the corresponding maximum length of the rod. SOLUTION (a) P ; A A d2 4 Substituting, we have P d2 4 d d 4P 4(4 103 N) (180 106 Pa) d 5.3192 103 m d 5.32 mm (b) E ; L Substituting, we have E L L L E (105 109 Pa) (3 103 m) (180 106 Pa) L 1.750 m PROPRIETARY MATERIAL.
Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 98 PROBLEM 2.7 A steel control rod is 5.5 ft long and must not
stretch more than 0.04 in. when a 2-kip tensile load is applied to it. Knowing that E 29 106 psi, determine (a) the smallest diameter rod that should be used, (b) the corresponding normal stress caused by the load. SOLUTION (a) PL AE : 0.04 in. (2000 lb) (5.5 12 in.) 6 A (29 10 psi) A 1 2 d 0.113793 in 2 4 d 0.38063 in. (b) P A 2000 lb 0.113793
in 2 d 0.381 in. 17.58 ksi 17575.8 psi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part.
99 PROBLEM 2.8 A cast-iron tube is used to support a compressive load. Knowing that E 10 106 psi and that the maximum allowable change in length is 0.025%, determine (a) the maximum normal stress in the tube, (b) the minimum wall thickness for a load of 1600 lb if the outside diameter of the tube is 2.0 in. SOLUTION (a) L 100 0.00025 E ;
E L L (10 106 psi)(0.00025) 2.50 103 psi 2.50 ksi (b) A P ; A 4 d 2 o di2 d o2 di2 A 1600 lb 0.64 in 2 2.50 103 psi 4A di2 (2.0 in.) 2 4(0.64 in 2) t P 3.1851 in 2 di 1.78469 in. 1 1 (d o di) (2.0 in. 1.78469 in.) 2 2 t 0.107655 in. t 0.1077 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary
material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 100 PROBLEM 2.9 A 4-m-long steel rod must not stretch more than 3 mm and the normal stress must not exceed 150 MPa when
the rod is subjected to a 10-kN axial load. Knowing that E 200 GPa, determine the required diameter of the rod. SOLUTION L 4m 3 103 m, 150 106 Pa E 200 109 Pa, P 10 103 N Stress: A Deformation: P A P 10 103 N 66.667 106 m 2 66.667 mm 2 6 150 10 Pa PL AE A PL (10 103)(4) 66.667 106 m 2 66.667 mm 2 E (200 109)(3 103)
The larger value of A governs: A 66.667 mm 2 A 4 d2 d 4A 4(66.667) d 9.21 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded,
distributed, or posted on a website, in whole or part. 101 PROBLEM 2.10 A nylon thread is to be subjected to a 10-N tension. Knowing that E 3.2 GPa, that the maximum allowable normal stress is 40 MPa, and that the length of the thread must not increase by more than 1%, determine the required diameter of the thread. SOLUTION Stress criterion:
40 MPa 40 106 Pa P 10 N A P P 10 N : A 250 109 m 2 A 40 106 Pa 4 d 2: d 2 A 250 109 2 564.19 106 m d 0.564 mm Elongation criterion: L 1% 0.01 PL : AE A P /E 10 N/3.2 109 Pa 312.5 109 m 2 /L 0.01 d 2 A 2 312.5 109 630.78 106 m 2 d 0.631 mm d 0.631 mm The required diameter is the larger value: PROPRIETARY
MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 102 PROBLEM 2.11 A block of 10-in. length and 1.8 ×
1.6-in. cross section is to support a centric compressive load P. The material to be used is a bronze for which E 14 × 106 psi. Determine the largest load that can be applied, knowing that the normal stress must not exceed 18 ksi and that the decrease in length of the block should be at most 0.12% of its original length. SOLUTION Considering
allowable stress, 18 ksi Cross-sectional area: A (1.8 in.)(1.6 in.) 2.880 in 2 P A or 18 103 psi P A (18 103 psi)(2.880 in 2) 5.1840 104 lb or 51.840 kips Considering allowable deformation, PL AE L 0.12% or 0.0012 in. P AE L P (2.880 in 2)(14 106 psi)(0.0012 in.) 4.8384 104 lb or 48.384 kips The smaller value for P resulting from the
required deformation criteria governs. 48.4 kips PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole
or part. 103 PROBLEM 2.12 A square yellow-brass bar must not stretch more than 2.5 mm when it is subjected to a tensile load. Knowing that E 105 GPa and that the allowable tensile strength is 180 MPa, determine (a) the maximum allowable length of the bar, (b) the required dimensions of the cross section if the tensile load is 40 kN. SOLUTION
180 106 Pa P 40 103 N E 105 109 Pa 2.5 103 m (a) PL L AE E E (105 109)(2.5 103) 1.45833 m L 180 106 L 1.458 m (b) A P A P A a2 40 103 222.22 106 m 2 222.22 mm 2 180 106 a A a 14.91 mm 222.22 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized
instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 104 P 130 kips PROBLEM 2.13 Rod BD is made of steel (E 29 106 psi) and is used to brace the axially compressed member ABC. The maximum force that can
be developed in member BD is 0.02P. If the stress must not exceed 18 ksi and the maximum change in length of BD must not exceed 0.001 times the length of ABC, determine the smallest-diameter rod that can be used for member BD. A 72 in. D B 72 in. C 54 in. SOLUTION FBD 0.02 P (0.02)(130) 2.6 kips 2.6 103 lb Considering stress, 18 ksi 18
103 psi FBD A A FBD 2.6 0.14444 in 2 18 Considering deformation, (0.001)(144) 0.144 in. FBD LBD AE A FBD LBD (2.6 103)(54) 0.03362 in 2 6 E (29 10)(0.144) Larger area governs. A 0.14444 in 2 A 4 d2 d 4A (4)(0.14444) d 0.429 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material
solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 105 PROBLEM 2.14 B 2.5 m The 4-mm-diameter cable BC is made of a steel with E 200 GPa. Knowing that the maximum stress in the cable
must not exceed 190 MPa and that the elongation of the cable must not exceed 6 mm, find the maximum load P that can be applied as shown. P 3.5 m A C 4.0 m SOLUTION LBC 62 42 7.2111 m Use bar AB as a free body. 4 FBC 0 3.5P (6) 7.2111 P 0.9509 FBC M A 0: Considering allowable stress, 190 106 Pa A d2 4 FBC A 4 (0.004) 2
12.566 106 m 2 FBC A (190 106)(12.566 106) 2.388 103 N Considering allowable elongation, 6 103 m FBC LBC AE FBC AE (12.566 106)(200 109)(6 103) 2.091 103 N 7.2111 LBC Smaller value governs. FBC 2.091 103 N P 0.9509 FBC (0.9509)(2.091 103) 1.988 103 N P 1.988 kN PROPRIETARY MATERIAL. Copyright © 2015
McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 106 PROBLEM 2.15 1.25-in. diameter d A single axial load of magnitude P = 15 kips is
applied at end C of the steel rod ABC. Knowing that E = 30 × 106 psi, determine the diameter d of portion BC for which the deflection of point C will be 0.05 in. A 4 ft B 3 ft C P SOLUTION C PLi PL PL Ai Ei AE AB AE BC LAB 4 ft 48 in.; AAB d2 4 LBC 3 ft 36 in. (1.25 in.)2 4 1.22718 in 2 Substituting, we have 15 103 lb 48 in. 36 in. 0.05
in. 6 2 ABC 30 10 psi 1.22718 in ABC 0.59127 in 2 ABC or d d d2 4 4 ABC 4(0.59127 in 2) d 0.86766 in. d 0.868 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied,
scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 107 PROBLEM 2.16 36 mm A 250-mm-long aluminum tube (E 70 GPa) of 36-mm outer diameter and 28-mm inner diameter can be closed at both ends by means of single-threaded screw-on covers of 1.5-mm pitch. With one cover screwed on tight, a solid brass rod (
E 105 GPa) of 25-mm diameter is placed inside the tube and the second cover is screwed on. Since the rod is slightly longer than the tube, it is observed that the cover must be forced against the rod by rotating it one-quarter of a turn before it can be tightly closed. Determine (a) the average normal stress in the tube and in the rod, (b) the
deformations of the tube and of the rod. 28 mm 25 mm 250 mm SOLUTION Atube A rod 4 4 (d o2 di2) d2 4 4 (362 282) 402.12 mm 2 402.12 106 m 2 (25)2 490.87 mm 2 490.87 106 m 2 PL P(0.250) 8.8815 109 P 9 Etube Atube (70 10)(402.12 106) PL P(0.250) 4.8505 109 P Erod Arod (105 106)(490.87 106) tube rod 1 turn 1.5
mm 0.375 mm 375 106 m 4 * tube * rod or tube rod * 8.8815 109 P 4.8505 109 P 375 106 P (a) tube P 27.308 103 67.9 106 Pa 6 Atube 402.12 10 rod (b) 0.375 103 27.308 103 N (8.8815 4.8505)(109) tube 67.9 MPa P 27.308 103 55.6 106 Pa 6 Arod 490.87 10 tube (8.8815 109)(27.308 103) 242.5 106 m rod (4.8505
109)(27.308 103) 132.5 106 m rod 55.6 MPa tube 0.243 mm rod 0.1325 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded,
distributed, or posted on a website, in whole or part. 108 P 5 350 lb B 0.4 in. C A 1 in. 1.6 in. D PROBLEM 2.17 P 5 350 lb 1 in. 2 in. 1.6 in. The specimen shown has been cut from a 14 -in.-thick sheet of vinyl (E = 0.45 × 106 psi) and is subjected to a 350-lb tensile load. Determine (a) the total deformation of the specimen, (b) the deformation of its
central portion BC. SOLUTION AB PLAB (350 lb)(1.6 in.) 4.9778 103 in. EAAB (0.45 106 psi)(1 in.)(0.25 in.) BC PLBC (350 lb)(2 in.) 15.5556 103 in. EABC (0.45 106 psi)(0.4 in.)(0.25 in.) CD AB 4.9778 103 in. (a) Total deformation: AB BC CD 25.511 103 in. 25.5 103 in. (b) Deformation of portion BC : BC 15.56 10 3 in.
PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 109 PROBLEM 2.18 P D 1 mm A The
brass tube AB (E 105 GPa) has a cross-sectional area of 140 mm2 and is fitted with a plug at A. The tube is attached at B to a rigid plate that is itself attached at C to the bottom of an aluminum cylinder (E 72 GPa) with a cross-sectional area of 250 mm2. The cylinder is then hung from a support at D. In order to close the cylinder, the plug must
move down through 1 mm. Determine the force P that must be applied to the cylinder. 375 mm B C SOLUTION Shortening of brass tube AB: LAB 375 1 376 mm 0.376 m AAB 140 mm 2 140 106 m 2 E AB 105 109 Pa AB PLAB P(0.376) 25.578 109P 6 9 E AB AAB (105 10)(140 10) Lengthening of aluminum cylinder CD: LCD 0.375 m CD
ACD 250 mm 2 250 106 m 2 ECD 72 109 Pa PLCD P(0.375) 20.833 109 P ECD ACD (72 109)(250 106) A AB CD where A 0.001 m Total deflection: 0.001 (25.578 109 20.833 109) P P 21.547 103 N P 21.5 kN PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized
instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 110 PROBLEM 2.19 P Both portions of the rod ABC are made of an aluminum for which E 70 GPa. Knowing that the magnitude of P is 4 kN, determine (a) the
value of Q so that the deflection at A is zero, (b) the corresponding deflection of B. A 20-mm diameter 0.4 m B Q 0.5 m 60-mm diameter C SOLUTION (a) AAB ABC 4 4 2 d AB 2 d BC 4 4 (0.020) 2 314.16 106 m 2 (0.060)2 2.8274 103 m 2 Force in member AB is P tension. Elongation: AB PLAB (4 103)(0.4) 72.756 106 m EAAB (70 109)
(314.16 106) Force in member BC is Q P compression. Shortening: BC (Q P) LBC (Q P)(0.5) 2.5263 109(Q P) 9 3 EABC (70 10)(2.8274 10) For zero deflection at A, BC AB 2.5263 109(Q P) 72.756 106 Q P 28.8 103 N Q 28.3 103 4 103 32.8 103 N Q 32.8 kN (b) AB BC B 72.756 106 m Q 32.8 kN AB 0.0728 mm PROPRIETARY
MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 111 PROBLEM 2.20 P The rod ABC is made of an
aluminum for which E 70 GPa. Knowing that P 6 kN and Q 42 kN, determine the deflection of (a) point A, (b) point B. A 20-mm diameter 0.4 m B Q 0.5 m 60-mm diameter C SOLUTION AAB ABC 4 4 2 d AB 2 d BC 4 4 (0.020)2 314.16 106 m 2 (0.060)2 2.8274 103 m 2 PAB P 6 103 N PBC P Q 6 103 42 103 36 103 N LAB 0.4 m LBC 0.5
m AB PAB LAB (6 103)(0.4) 109.135 106 m 6 9 AAB E A (314.16 10)(70 10) BC PBC LBC (36 103)(0.5) 90.947 106 m ABC E (2.8274 103)(70 109) (a) A AB BC 109.135 106 90.947 106 m 18.19 106 m (b) B BC 90.9 106 m 0.0909 mm or A 0.01819 mm B 0.0909 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill
Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 112 228 kN PROBLEM 2.21 D For the steel truss (E 200 GPa) and loading shown, determine the
deformations of the members AB and AD, knowing that their cross-sectional areas are 2400 mm2 and 1800 mm2, respectively. B A 4.0 m 2.5 m C 4.0 m SOLUTION Statics: Reactions are 114 kN upward at A and C. Member BD is a zero force member. LAB 4.02 2.52 4.717 m Use joint A as a free body. Fy 0 : 114 2.5 FAB 0 4.717 FAB 215.10 kN Fx
0 : FAD FAD 4 FAB 0 4.717 (4)(215.10) 182.4 kN 4.717 Member AB: AB FAB LAB (215.10 103)(4.717) EAAB (200 109)(2400 106) 2.11 103 m Member AD: AD AB 2.11 mm FAD LAD (182.4 103)(4.0) EAAD (200 109)(1800 106) 2.03 103 m AD 2.03 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is
proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 113 30 kips A PROBLEM 2.22 30 kips B For the steel truss (E 29 106 psi) and loading shown, determine the
deformations of the members BD and DE, knowing that their crosssectional areas are 2 in2 and 3 in2, respectively. 8 ft C 8 ft 30 kips D E 8 ft F G 15 ft SOLUTION Free body: Portion ABC of truss M E 0 : FBD (15 ft) (30 kips)(8 ft) (30 kips)(16 ft) 0 FBD 48.0 kips Free body: Portion ABEC of truss Fx 0 : 30 kips 30 kips FDE 0 FDE 60.0 kips BD
PL (48.0 103 lb)(8 12 in.) AE (2 in 2)(29 106 psi) DE PL (60.0 103 lb)(15 12 in.) AE (3 in 2)(29 106 psi) BD 79.4 103 in. DE 124.1 103 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This
document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 114 6 ft PROBLEM 2.23 6 ft C B 5 ft A D 28 kips Members AB and BC are made of steel (E 29 106 psi) with crosssectional areas of 0.80 in2 and 0.64 in2, respectively. For the loading shown, determine the elongation of (a) member AB,
(b) member BC. E 54 kips SOLUTION (a) LAB 62 52 7.810 ft 93.72 in. Use joint A as a free body. 5 FAB 28 0 7.810 43.74 kip 43.74 103 lb Fy 0: FAB AB (b) FAB LAB (43.74 103)(93.72) EAAB (29 106)(0.80) AB 0.1767 in. Use joint B as a free body. Fx 0: FBC FBC BC 6 FAB 0 7.810 (6)(43.74) 33.60 kip 33.60 103 lb 7.810 FBC LBC
(33.60 103)(72) EABC (29 106)(0.64) BC 0.1304 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in
whole or part. 115 P B C A D PROBLEM 2.24 The steel frame (E 200 GPa) shown has a diagonal brace BD with an area of 1920 mm2. Determine the largest allowable load P if the change in length of member BD is not to exceed 1.6 mm. 6m 5m SOLUTION BD 1.6 103 m, ABD 1920 mm 2 1920 106 m 2 52 62 7.810 m, EBD 200 109 Pa LBD BD
FBD LBD EBD ABD FBD (200 109)(1920 106)(1.6 103) EBD ABD BD 7.81 LBD 78.67 103 N Use joint B as a free body. Fx 0: 5 FBD P 0 7.810 P 5 (5)(78.67 103) FBD 7.810 7.810 50.4 103 N P 50.4 kN PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not
authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 116 PROBLEM 2.25 D 225 mm C A B 150 mm P Link BD is made of brass (E 105 GPa) and has a cross-sectional area of 240 mm2. Link CE is made of aluminum (E 72 GPa) and
has a crosssectional area of 300 mm2. Knowing that they support rigid member ABC, determine the maximum force P that can be applied vertically at point A if the deflection of A is not to exceed 0.35 mm. E 225 mm 125 mm SOLUTION Free body member AC: M C 0: 0.350 P 0.225FBD 0 FBD 1.55556 P M B 0: 0.125P 0.225 FCE 0 FCE 0.55556 P
FBD LBD (1.55556 P)(0.225) 13.8889 109 P EBD ABD (105 109)(240 106) F L (0.55556 P)(0.150) CE CE 3.8581 109 P ECE ACE (72 109)(300 106) B BD C CE Deformation Diagram: From the deformation diagram, Slope: B C LBC A B LAB 17.7470 109 P 78.876 109 P 0.225 13.8889 109 P (0.125)(78.876 109 P) 23.748 109 P
Apply displacement limit. A 0.35 103 m 23.748 109P P 14.7381 103 N P 14.74 kN PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded,
distributed, or posted on a website, in whole or part. 117 PROBLEM 2.26 F C 180 mm B E A D Members ABC and DEF are joined with steel links (E 200 GPa). Each of the links is made of a pair of 25 × 35-mm plates. Determine the change in length of (a) member BE, (b) member CF. 260 mm 18 kN 240 mm 18 kN SOLUTION Free body diagram of
Member ABC: M B 0: (0.26 m)(18 kN) (0.18 m) FCF 0 FCF 26.0 kN Fx 0: 18 kN FBE 26.0 kN 0 FBE 44.0 kN Area for link made of two plates: A 2(0.025 m)(0.035 m) 1.750 103 m 2 (a) BE FBE L (44.0 103 N)(0.240 m) EA (200 109 Pa)(1.75 103 m 2) 30.171 106 m BE 0.0302 mm (b) CF FBF L (26.0 103 N)(0.240 m) EA (200 109 Pa)
(1.75 103 m 2) 17.8286 106 m CF 0.01783 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in
whole or part. 118 A D P = 1 kip Each of the links AB and CD is made of aluminum (E 10.9 106 psi) and has a cross-sectional area of 0.2 in2. Knowing that they support the rigid member BC, determine the deflection of point E. 18 in. E B 22 in. PROBLEM 2.27 C 10 in. SOLUTION Free body BC: M C 0: (32) FAB (22) (1 103) 0 FAB 687.5 lb Fy 0:
687.5 1 103 FCD 0 FCD 312.5 lb FAB LAB (687.5)(18) 5.6766 103 in. B EA (10.9 106)(0.2) F L (312.5)(18) CD CD 2.5803 103 in. C EA (10.9 106)(0.2) AB CD Deformation diagram: Slope B C LBC 3.0963 103 32 96.759 106 rad E C LEC 2.5803 103 (22)(96.759 106) 4.7090 103 in. E 4.71 10 3 in. PROPRIETARY MATERIAL.
Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 119 PROBLEM 2.28 D 3 The length of the 32 -in.-diameter steel wire
CD has been adjusted so that with no load applied, a gap of 161 in. exists between the end B of the rigid beam ACB and a contact point E. Knowing that E 29 106 psi, determine where a 50-lb block should be placed on the beam in order to cause contact between B and E. 12.5 in. x C 50 lb B A E 16 in. 1 16 in. 4 in. SOLUTION Rigid beam ACB rotates
through angle to close gap. 1/16 3.125 103 rad 20 Point C moves downward. C 4 4(3.125 103) 12.5 103 in. CD C 12.5 103 in. ACD CD 2 d 3 d F L CD CD EACD FCD 2 6.9029 103 in 2 4 32 EACD CD (29 106)(6.9029 103)(12.5 103) LCD 12.5 200.18 lb Free body ACB: M A 0: 4 FCD (50)(20 x) 0 (4)(200.18) 16.0144 50 x 3.9856
in. 20 x x 3.99 in. For contact, PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 120
PROBLEM 2.29 A homogeneous cable of length L and uniform cross section is suspended from one end. (a) Denoting by the density (mass per unit volume) of the cable and by E its modulus of elasticity, determine the elongation of the cable due to its own weight. (b) Show that the same elongation would be obtained if the cable were horizontal and if
a force equal to half of its weight were applied at each end. SOLUTION (a) For element at point identified by coordinate y, P weight of portion below the point gA(L y) d Pdy gA(L y)dy g (L y) dy EA EA E (b) Total weight: L g (L y) E 0 g L 1 dy Ly y 2 2 0 E g L2 2 L 2 E 1 gL2 2 E W gAL F EA EA 1 gL2 1 gAL 2 L L 2 E 1 F W 2
PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 121 PROBLEM 2.30 P A a A vertical load
P is applied at the center A of the upper section of a homogeneous frustum of a circular cone of height h, minimum radius a, and maximum radius b. Denoting by E the modulus of elasticity of the material and neglecting the effect of its weight, determine the deflection of point A. h b SOLUTION Extend the slant sides of the cone to meet at a point O
and place the origin of the coordinate system there. tan From geometry, a1 ba h a b , b1 , tan tan r y tan At coordinate point y, A r 2 Deformation of element of height dy: d Pdy AE d P dy P dy E r 2 E tan 2 y 2 Total deformation: P A E tan 2 b1 a1 1 dy P 2 2 E tan y y b1 a1 P(b1 a1) P 2 Eab E tan a1b1 b1 a1 P E tan 2 1 1 a1 b1
A Ph Eab PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 122 PROBLEM 2.31
Denoting by the "engineering strain" in a tensile specimen, show that the true strain is t ln (1). SOLUTION t ln L L ln 0 ln 1 ln (1) L0 L0 L0 t ln (1) Thus, PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any
manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 123 PROBLEM 2.32 The volume of a tensile specimen is essentially constant while plastic deformation occurs. If the initial diameter of the specimen is d1, show that when the diameter is d, the true strain is t 2 ln(d1 /d).
SOLUTION If the volume is constant, 4 d 2L 4 d12 L0 L d12 d1 L0 d 2 d t ln 2 L d ln 1 L0 d 2 t 2ln d1 d PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned,
duplicated, forwarded, distributed, or posted on a website, in whole or part. 124 Brass core (E = 105 GPa) Aluminum plates (E = 70 GPa) P PROBLEM 2.33 Rigid end plate An axial centric force of magnitude P 450 kN is applied to the composite block shown by means of a rigid end plate. Knowing that h 10 mm, determine the normal stress in (a) the
brass core, (b) the aluminum plates. 300 mm 60 mm h 40 mm h SOLUTION A B ; PA L E A AA P PA PB and PB L EB AB Therefore, PA (E A AA) ; L Substituting, PA E A AA E B AB L L P E A AA EB AB (450 103 N) (70 109 Pa)(2)(0.06 m)(0.01 m) (105 109 Pa)(0.06 m)(0.04 m) 1.33929 103 E Now, (a) PB (EB AB) L Brass-core:
B (105 109 Pa)(1.33929 103) 1.40625 108 Pa B 140.6 MPa (b) Aluminum: A (70 109 Pa)(1.33929 103) 9.3750 107 Pa A 93.8 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may
not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 125 Brass core (E = 105 GPa) Aluminum plates (E = 70 GPa) P Rigid end plate PROBLEM 2.34 For the composite block shown in Prob. 2.33, determine (a) the value of h if the portion of the load carried by the aluminum plates is half the portion of the
load carried by the brass core, (b) the total load if the stress in the brass is 80 MPa. PROBLEM 2.33. An axial centric force of magnitude P 450 kN is applied to the composite block shown by means of a rigid end plate. Knowing that h 10 mm, determine the normal stress in (a) the brass core, (b) the aluminum plates. 300 mm 60 mm h 40 mm h
SOLUTION a b; Pa L Ea Aa P Pa Pb and Pb L Eb Ab Therefore, Pa (Ea Aa) ; L Pa (a) Pb (Eb Ab) L 1 Pb 2 1 (Ea Aa) (Eb Ab) L 2 L Aa 1 Eb Ab 2 E a Aa 1 105 GPa (40 mm)(60 mm) 2 70 GPa Aa 1800 mm 2 1800 mm 2 2(60 mm)(h) h 15.00 mm (b) b Pb 1 Pb b Ab and Pa Pb 2 Ab P Pa Pb PROPRIETARY MATERIAL.
Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 126 PROBLEM 2.34 (Continued) P 1 (b Ab) b Ab 2 P (b Ab)1.5 P
(80 106 Pa)(0.04 m)(0.06 m)(1.5) P 2.880 105 N P 288 kN PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a
website, in whole or part. 127 PROBLEM 2.35 P The 4.5-ft concrete post is reinforced with six steel bars, each with a 1 18 -in. diameter. Knowing that Es 29 × 106 psi and Ec = 4.2 × 106 psi, determine the normal stresses in the steel and in the concrete when a 350-kip axial centric force P is applied to the post. 18 in. 4.5 ft SOLUTION Let Pc portion
of axial force carried by concrete. Ps portion carried by the six steel rods. Pc L Ec Ac Pc Ec Ac L Ps L Es As Ps Es As L P Pc Ps (Ec Ac Es As) L As 6 Ac 4 L P Ec Ac Es As d s2 6 (1.125 in.) 2 5.9641 in 2 4 d c2 As 4 248.51 in 2 4 (18 in.)2 5.9641 in 2 L 4.5 ft 54 in. 350 103 lb 2.8767 104 6 2 6 2 (4.2 10 psi)(248.51 in) (29 10 psi)
(5.9641 in) s Es (29 106 psi)(2.8767 10 4) 8.3424 10 psi s 8.34 ksi c Ec (4.2 106 psi)(2.8767 104) 1.20821 103 psi c 1.208 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may
not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 128 PROBLEM 2.36 P 18 in. For the post of Prob. 2.35, determine the maximum centric force that can be applied if the allowable normal stress is 20 ksi in the steel and 2.4 ksi in the concrete. PROBLEM 2.35 The 4.5-ft concrete post is reinforced with
six steel bars, each with a 1 18 -in. diameter. Knowing that Es 29 × 106 psi and Ec 4.2 × 106 psi, determine the normal stresses in the steel and in the concrete when a 350-kip axial centric force P is applied to the post. 4.5 ft SOLUTION Allowable strain in each material: Steel: s Concrete: c Smaller value governs. s Es c Ec L 20 103 psi 6.8966
104 6 29 10 psi 2.4 103 psi 5.7143 104 4.2 106 psi 5.7143 104 Let Pc = Portion of load carried by concrete. Ps = Portion of load carried by 6 steel rods. Pc L E c Ac Pc Ec Ac Ec Ac L Ps L E s As Ps Es As Es As L 6 As 6 d s2 (1.125 in.) 2 5.9641 in 2 4 4 Ac d c2 As (18 in.) 2 5.9641 in 2 2.4851 102 in 2 4 4 P Pc Ps Ec Ac Es
As P [(4.2 106 psi)(2.4851 102 in 2) (29 106 psi)(5.9641 in 2)](5.7143 104) P 6.9526 105 lb P 695 kips PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned,
duplicated, forwarded, distributed, or posted on a website, in whole or part. 129 PROBLEM 2.37 25 mm Brass core E 105 GPa An axial force of 200 kN is applied to the assembly shown by means of rigid end plates. Determine (a) the normal stress in the aluminum shell, (b) the corresponding deformation of the assembly. 300 mm Aluminium shell E
70 GPa 60 mm SOLUTION Let Pa = Portion of axial force carried by shell. Pb = Portion of axial force carried by core. Pa L , or Ea Aa Pa Ea Aa L Pb L , or Eb Ab Pb Eb Ab L P Pa Pb (Ea Aa Eb Ab) Thus, Aa with Ab 4 4 L [(0.060) 2 (0.025)2] 2.3366 103 m 2 (0.025)2 0.49087 103 m 2 P [(70 109)(2.3366 103) (105 109)(0.49087 103)]
P 215.10 10 Strain: L 6 L L P 200 103 0.92980 103 6 6 215.10 10 215.10 10 (a) a Ea (70 109)(0.92980 103) 65.1 106 Pa (b) L (0.92980 103)(300 mm) a 65.1 MPa 0.279 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for
sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 130 25 mm Brass core E 105 GPa PROBLEM 2.38 The length of the assembly shown decreases by 0.40 mm when an axial force is applied by means of rigid end plates. Determine (a) the
magnitude of the applied force, (b) the corresponding stress in the brass core. 300 mm Aluminium shell E 70 GPa 60 mm SOLUTION Let Pa = Portion of axial force carried by shell and Pb = Portion of axial force carried by core. Thus, with Pa L , or Ea Aa Pa Ea Aa L Pb L , or Eb Ab Pb Eb Ab L P Pa Pb (Ea Aa Eb Ab) Aa Ab 4 4 L [(0.060) 2
(0.025)2] 2.3366 103 m 2 (0.025)2 0.49087 103 m 2 P [(70 109)(2.3366 103) (105 109)(0.49087 103)] with L 215.10 106 L 0.40 mm, L 300 mm (a) P (215.10 106) (b) b 0.40 286.8 103 N 300 P 287 kN Pb E (105 109)(0.40 103) b 140 106 Pa Ab L 300 103 b 140.0 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill
Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 131 PROBLEM 2.39 A 25 in. 1.25 in. 6 kips 6 kips B A polystyrene rod consisting of two cylindrical
portions AB and BC is restrained at both ends and supports two 6-kip loads as shown. Knowing that E 0.45 106 psi, determine (a) the reactions at A and C, (b) the normal stress in each portion of the rod. 2 in. 15 in. C SOLUTION (a) We express that the elongation of the rod is zero. But PAB LAB d2 E 4 AB PAB RA PBC LBC 4 2 d BC E 0 PBC RC
Substituting and simplifying, RA LAB RC LBC 2 0 2 d AB d BC L RC AB LBC 2 2 d BC 25 2 RA RA 15 1.25 d AB RC 4.2667 RA From the free body diagram, Substituting (1) into (2), RA RC 12 kips (2) 5.2667 RA 12 RA 2.2785 kips From (1), (1) RA 2.28 kips RC 4.2667 (2.2785) 9.7217 kips RC 9.72 kips (b) AB PAB RA 2.2785 AAB AAB
(1.25) 2 4 AB 1.857 ksi BC PBC RC 9.7217 (2) 2 ABC ABC 4 BC 3.09 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or
posted on a website, in whole or part. 132 PROBLEM 2.40 C A P Three steel rods (E = 29 × 106 psi) support an 8.5-kip load P. Each of the rods AB and CD has a 0.32-in2 cross-sectional area and rod EF has a 1-in2 cross-sectional area. Neglecting the deformation of bar BED, determine (a) the change in length of rod EF, (b) the stress in each rod. 20
in. B D E 16 in. F SOLUTION Use member BED as a free body. By symmetry, or by M E 0 : PCD PAB Fy 0: PAB PCD PEF P 0 P 2 PAB PEF AB PAB LAB EAAB CD PCD LCD EACD EF PEF LEF EAEF LAB LCD and AAB ACD , AB CD Since Since points A, C, and F are fixed, B AB , D CD , E EF Since member BED is rigid, E B C PAB
LAB PEF LEF EAAB EAEF PAB AAB LEF 0.32 16 PEF PEF 0.256 PEF 1 20 AEF LAB P 2 PAB PEF 2(0.256 PEF) PEF 1.512 PEF P 8.5 5.6217 kips 1.512 1.512 PCD 0.256(5.6217) 1.43916 kips PEF PAB (a) PEF LEF (5.6217)(16) 0.0031016 in. EAEF (29 103)(1) P 1.43916 CD AB 4.4974 ksi 0.32 AAB EF (b) AB EF PEF 5.6217
5.6217 ksi 1 AEF EF 0.00310 in. AB CD 4.50 ksi EF 5.62 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a
website, in whole or part. 133 PROBLEM 2.41 Dimensions in mm 180 100 120 A C Steel B D Brass 60 kN 40-mm diam. 100 E 40 kN Two cylindrical rods, one of steel and the other of brass, are joined at C and restrained by rigid supports at A and E. For the loading shown and knowing that Es 200 GPa and Eb 105 GPa, determine (a) the reactions at
A and E, (b) the deflection of point C. 30-mm diam. SOLUTION A to C: E 200 109 Pa A (40) 2 1.25664 103 mm 2 1.25664 103 m 2 4 EA 251.327 106 N C to E: E 105 109 Pa A (30)2 706.86 mm 2 706.86 106 m 2 4 EA 74.220 106 N A to B: P RA L 180 mm 0.180 m RA (0.180) PL EA 251.327 106 716.20 1012 RA AB B to C: P RA 60 103
L 120 mm 0.120 m BC PL (RA 60 103)(0.120) EA 251.327 106 447.47 1012 RA 26.848 106 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated,
forwarded, distributed, or posted on a website, in whole or part. 134 PROBLEM 2.41 (Continued) C to D: P RA 60 103 L 100 mm 0.100 m PL (RA 60 103)(0.100) EA 74.220 106 1.34735 109 RA 80.841 106 BC D to E: P RA 100 103 L 100 mm 0.100 m DE PL (RA 100 103)(0.100) EA 74.220 106 1.34735 109 RA 134.735 106 A to E:
AE AB BC CD DE 3.85837 109 RA 242.424 106 Since point E cannot move relative to A, (a) AE 0 3.85837 109 RA 242.424 106 0 RA 62.831 103 N RA 62.8 kN RE RA 100 103 62.8 103 100 103 37.2 103 N RE 37.2 kN C AB BC 1.16367 109 RA 26.848 106 (1.16369 109)(62.831 103) 26.848 106 46.3 106 m C 46.3 m
PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 135 PROBLEM 2.42 Dimensions in mm
180 100 120 A C Steel B D Brass 60 kN 40-mm diam. 100 E 40 kN 30-mm diam. Solve Prob. 2.41, assuming that rod AC is made of brass and rod CE is made of steel. PROBLEM 2.41 Two cylindrical rods, one of steel and the other of brass, are joined at C and restrained by rigid supports at A and E. For the loading shown and knowing that Es 200 GPa
and Eb 105 GPa, determine (a) the reactions at A and E, (b) the deflection of point C. SOLUTION A to C: E 105 109 Pa (40) 2 1.25664 103 mm 2 1.25664 103 m 2 4 EA 131.947 106 N A C to E: E 200 109 Pa (30)2 706.86 mm 2 706.86 106 m 2 4 EA 141.372 106 N A A to B: P RA L 180 mm 0.180 m AB RA (0.180) PL EA 131.947 106
1.36418 109 RA B to C: P RA 60 103 L 120 mm 0.120 m BC PL (RA 60 103)(0.120) EA 131.947 106 909.456 1012 RA 54.567 106 C to D: P RA 60 103 L 100 mm 0.100 m CD PL (RA 60 103)(0.100) EA 141.372 106 707.354 1012 RA 42.441 106 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is
proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 136 PROBLEM 2.42 (Continued) D to E: P RA 100 103 L 100 mm 0.100 m DE PL (RA 100 103)(0.100) EA
141.372 106 707.354 1012 RA 70.735 106 A to E: AE AB BC CD DE 3.68834 109 RA 167.743 106 Since point E cannot move relative to A, (a) AE 0 3.68834 109 RA 167.743 106 0 RA 45.479 103 N RE RA 100 103 45.479 103 100 103 54.521 103 (b) R A 45.5 kN RE 54.5 kN C AB BC 2.27364 109 RA 54.567 106 (2.27364
109)(45.479 103) 54.567 106 48.8 106 m C 48.8 m PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website,
in whole or part. 137 D PROBLEM 2.43 E 2 kN 225 mm B A F C Each of the rods BD and CE is made of brass (E 105 GPa) and has a cross-sectional area of 200 mm2. Determine the deflection of end A of the rigid member ABC caused by the 2-kN load. 550 mm 75 mm 100 mm SOLUTION Let be the rotation of member ABC as shown. Then A 0.6251
But B PBD B 0.0751 C 0.1 PBD LBD AE EA B (105 109)(200 10 6)(0.075) 0.225 LBD 7 106 Free body ABC: C PCE LCE AE PCE EA C (105 109)(200 10 6)(0.1) 0.225 LCE 9.3333 106 From free body of member ABC: M F 0 : (0.625)(2000) 0.075 PBD 0.1PCE 0 or (0.625)(2000) 0.075(7 106) 0.1(9.3333 106) 0 0.85714 103 rad
and A 0.625 0.625(0.85714 103) 0.53571 103 m A 0.536 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a
website, in whole or part. 138 PROBLEM 2.44 F 8 in. E 10 in. A B C P D 12 in. 12 in. The rigid bar AD is supported by two steel wires of 161 -in. diameter (E 29 × 106 psi) and a pin and bracket at A. Knowing that the wires were initially taut, determine (a) the additional tension in each wire when a 220-lb load P is applied at D, (b) the corresponding
deflection of point D. 12 in. SOLUTION Let be the notation of bar ABCD. Then B 12 C 24 B PBE LBE AE EA BE LBE PBE (29 106) 1 2 (12)4 6 10 106.765 103 C PCF PCF LCF EA EA CE LCF (29 106) 1 2 (24) 4 16 18 118.628 103 Using free body ABCD, MA 0 : 12 PBE 24 PCF 36 P 0 (12)(106.765 103) (24)(118.628 106) (36)
(220) 0 4.1283 106 (36)(220) 1.91847 103 rad (a) (b) PBE (106.765 103)(1.91847 103) 204.83 lb PBE 205 lb PCF (118.628 103)(1.91847 10 3) 227.58 lb PCF 228 lb D 36 (36)(1.91847 103) 69.1 103 in. 0.0691 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized
instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 139 L B D A 3 4 L PROBLEM 2.45 L C The rigid bar ABC is suspended from three wires of the same material. The crosssectional area of the wire at B is equal to
half of the cross-sectional area of the wires at A and C. Determine the tension in each wire caused by the load P shown. P SOLUTION M A 0: PC 3 LP 0 4 3 1 P PB 8 2 M C 0: PA 2 LPC LPB 2 LPA LPB 5 LP 0 4 5 1 P PB 8 2 Let l be the length of the wires. A PAl l 5 1 P PB 2 EA EA 8 B PB l 2l PB E (A/2) EA C PC l 1 l 3 P PB 2 EA EA 8
From the deformation diagram, A B B C or 1 2 B (A c) l 1 l 5 1 3 1 PB P PB P PB 2 EA 8 2 8 2 E (A / 2) 5 1 PB P; 2 2 PB 1 P 5 PB 0.200 P PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This
document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 140 PROBLEM 2.45 (Continued) PA 5 1 P 21 P P 8 2 5 40 PA 0.525 P PC 3 1 P 11 P P 8 2 5 40 PC 0.275P Check: PA PB PC 1.000 P Ok PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is
proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 141 PROBLEM 2.46 E The rigid bar AD is supported by two steel wires of 161 -in. diameter (E 29 106 psi) and a pin
and bracket at D. Knowing that the wires were initially taut, determine (a) the additional tension in each wire when a 120-lb load P is applied at B, (b) the corresponding deflection of point B. F 15 in. 8 in. A B C 8 in. 8 in. D 8 in. P SOLUTION Let be the rotation of bar ABCD. Then A 24 C 8 A PAE PAE LAE AE 6 2 EA A (29 10) 4 (161) (24) LAE
15 142.353 103 C PCF LCF AE 6 1 EA C (29 10) 4 16 (8) 8 LCF 2 PCF 88.971 103 Using free body ABCD, M D 0 : 24PAE 16 P 8PCF 0 24(142.353 103) 16(120) 8(88.971 103) 0 0.46510 103 rad吗 (a) (b) PAE (142.353 103)(0.46510 103) PAE 66.2 lb PCF (88.971 103)(0.46510 103) PCF 41.4 lb B 7.44 103 in. B 16
16(0.46510 103) PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 142 PROBLEM 2.47 25
mm The aluminum shell is fully bonded to the brass core and the assembly is unstressed at a temperature of 15C. Considering only axial deformations, determine the stress in the aluminum when the temperature reaches 195C. Brass core E 105 GPa 20.9 10–6/C Aluminum shell E 70 GPa 23.6 10–6/C 60 mm SOLUTION Brass core: E 105 GPa
20.9 106/ C Aluminum shell: E 70 GPa 23.6 106 / C Let L be the length of the assembly. Free thermal expansion: T 195 15 180 C Brass core: Aluminum shell: (T)b L b (T) (T) a L a (T) Net expansion of shell with respect to the core: L(a b)(T) Let P be the tensile force in the core and the compressive force in the shell. Brass core: Eb 105
109 Pa (25)2 490.87 mm 2 4 490.87 106 m 2 Ab (P)b PL Eb Ab PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a
website, in whole or part. 143 PROBLEM 2.47 (Continued) Aluminum shell: (p)a PL Ea Aa Ea 70 109 Pa (602 252) 4 2.3366 103 mm 2 Aa 2.3366 103 m 2 (P)b (P)a L(b a)(T) PL PL KPL Eb Ab Ea Aa where K 1 1 Eb Ab Ea Aa 1 1 6 9 (105 10)(490.87 10) (70 10)(2.3366 103) 9 25.516 109 N 1 Then (b a)(T) K (23.6 106 20.9
106)(180) 25.516 109 19.047 103 N P Stress in aluminum: a P 19.047 103 8.15 106 Pa 3 Aa 2.3366 10 a 8.15 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied,
scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 144 PROBLEM 2.48 25 mm Solve Prob. 2.47, assuming that the core is made of steel (Es 200 GPa, s 11.7 106 / C) instead of brass. Brass core E 105 GPa 20.9 10–6/C PROBLEM 2.47 The aluminum shell is fully bonded to the brass core and the assembly is
unstressed at a temperature of 15C. Considering only axial deformations, determine the stress in the aluminum when the temperature reaches 195C. Aluminum shell E 70 GPa 23.6 10–6/C 60 mm SOLUTION E 70 GPa 23.6 106 / C Aluminum shell: Let L be the length of the assembly. T 195 15 180 C Free thermal expansion: Steel core: (T) s L s
(T) Aluminum shell: (T)a L a (T) L(a s)(T) Net expansion of shell with respect to the core: Let P be the tensile force in the core and the compressive force in the shell. Es 200 109 Pa, As Steel core: 4 (25) 2 490.87 mm 2 490.87 106 m 2 PL (P) s Es As Ea 70 109 Pa Aluminum shell: (P)a PL Ea Aa (602 25)2 2.3366 103 mm 2 2.3366
103 m 2 4 (P) s (P) a Aa L(a s)(T) PL PL KPL Es As Ea Aa where K 1 1 Es As Ea Aa 1 1 6 9 (200 10)(490.87 10) (70 10)(2.3366 103) 9 16.2999 109 N 1 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any
manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 145 PROBLEM 2.48 (Continued) Then P (a s)(T) (23.6 10 6 11.7 10 6)(180) 131.412 103 N K 16.2999 10 9 Stress in aluminum: a P 131.412 103 56.241 106 Pa 3 Aa 2.3366 10 a 56.2 MPa PROPRIETARY
MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 146 1 4 1 4 in. 1 in. 1 in. 1 4 in. PROBLEM 2.49 1 in. 1 4
in. Steel core E 29 106 psi Brass shell E 15 106 psi The brass shell (b 11.6 106 /F) is fully bonded to the steel core (s 6.5 106 /F). Determine the largest allowable increase in temperature if the stress in the steel core is not to exceed 8 ksi. 12 in. SOLUTION Let Ps axial force developed in the steel core. For equilibrium with zero total force, the
compressive force in the brass shell is Ps . s Strains: Ps s (T) Es As b Ps b (T) Eb Ab s b Matching: Ps P s (T) s b (T) Es As Eb Ab 1 1 Ps (b s)(T) Es As Eb Ab (1) Ab (1.5)(1.5) (1.0)(1.0) 1.25 in 2 As (1.0)(1.0) 1.0 in 2 b s 5.1 106 /F Ps s As (8 103)(1.0) 8 103 lb 1 1 1 1 87.816 109 lb 1 6 Es As Eb Ab (29 10)(1.0) (15 106)
(1.25) From (1), (87.816 109)(8 103) (5.1 106)(T) T 137.8 F PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a
website, in whole or part. 147 PROBLEM 2.50 The concrete post (Ec 3.6 106 psi and c 5.5 106 / F) is reinforced with six steel bars, each of 78 -in. diameter (Es 29 106 psi and s 6.5 106 / F). Determine the normal stresses induced in the steel and in the concrete by a temperature rise of 65°F. 6 ft 10 in. 10 in. SOLUTION As 6 4 2 d 6 7 2
3.6079 in 2 48 Ac 102 As 102 3.6079 96.392 in 2 Let Pc tensile force developed in the concrete. For equilibrium with zero total force, the compressive force in the six steel rods equals Pc . Strains: s Pc s (T) Es As c Pc c (T) Ec Ac Pc P c (T) c s (T) Ec Ac Es As Matching: c s 1 1 Pc (s c)(T) Ec Ac Es As 1 1 6 Pc (1.0 10)(65) 6
6 (3.6 10)(96.392) (29 10)(3.6079) Pc 5.2254 103 lb c Pc 5.2254 103 54.210 psi 96.392 Ac s c 54.2 psi Pc 5.2254 103 1448.32 psi 3.6079 As s 1.448 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any
manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 148 PROBLEM 2.51 A A rod consisting of two cylindrical portions AB and BC is restrained at both ends. Portion AB is made of steel (Es 200 GPa, s 11.7 106 / C) and portion BC is made of brass (Eb 105 GPa, b 20.9
106 / C). Knowing that the rod is initially unstressed, determine the compressive force induced in ABC when there is a temperature rise of 50 C. 30-mm diameter 250 mm B 50-mm diameter 300 mm C SOLUTION AAB ABC 4 4 2 d AB 2 d BC 4 4 (30) 2 706.86 mm 2 706.86 106 m 2 (50)2 1.9635 103 mm 2 1.9635 103 m 2 Free thermal
expansion: T LAB s (T) LBC b (T) (0.250)(11.7 106)(50) (0.300)(20.9 10 6)(50) 459.75 106 m Shortening due to induced compressive force P: P PL PL Es AAB Eb ABC 0.250 P 0.300 P 6 9 (200 10)(706.86 10) (105 10)(1.9635 103) 9 3.2235 109 P For zero net deflection, P T 3.2235 109 P 459.75 106 P 142.624 103 N P 142.6 kN
PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 149 24 in. A PROBLEM 2.52 32 in. B C 1
2 14 -in. diameter 1 2 -in. diameter A rod consisting of two cylindrical portions AB and BC is restrained at both ends. Portion AB is made of steel (Es 29 106 psi, s 6.5 106 / F) and portion BC is made of aluminum (Ea 10.4 106 psi, a 13.3 106 /°F). Knowing that the rod is initially unstressed, determine (a) the normal stresses induced in portions
AB and BC by a temperature rise of 70°F, (b) the corresponding deflection of point B. SOLUTION AAB Free thermal expansion. 4 (2.25) 2 3.9761 in 2 ABC 4 (1.5)2 1.76715 in 2 T 70F (T) AB LAB s (T) (24)(6.5 106)(70) 10.92 103 in. (T) BC LBC a (T) (32)(13.3 106)(70) 29.792 103 in. T (T) AB (T) BC 40.712 103 in. Total: Shortening
due to induced compressive force P. PLAB 24 P 208.14 109 P Es AAB (29 106)(3.9761) PLBC 32 P 1741.18 109 P 6 Ea ABC (10.4 10)(1.76715) (P) AB (P) BC P (P) AB (P) BC 1949.32 109 P Total: For zero net deflection, P T (a) (b) 1949.32 109 P 40.712 103 AB P 20.885 103 5.25 103 psi AAB 3.9761 BC P 20.885 103 11.82
103 psi ABC 1.76715 P 20.885 103 lb AB 5.25 ksi BC 11.82 ksi (P) AB (208.14 109)(20.885 103) 4.3470 103 in. B (T) AB (P) AB 10.92 103 4.3470 103 B 6.57 103 in. or (P) BC (1741.18 109)(20.885 103) 36.365 103 in. B (T) BC (P) BC 29.792 103 36.365 103 6.57 103 in. (checks) PROPRIETARY MATERIAL.
Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 150 PROBLEM 2.53 24 in. A Solve Prob. 2.52, assuming that portion
AB of the composite rod is made of aluminum and portion BC is made of steel. 32 in. B C 1 2 14 -in. diameter 1 2 -in. diameter PROBLEM 2.52 A rod consisting of two cylindrical portions AB and BC is restrained at both ends. Portion AB is made of steel (Es 29 106 psi, s 6.5 106 /F) and portion BC is made of aluminum (Ea 10.4 106 psi, a 13.3
106 /°F). Knowing that the rod is initially unstressed, determine (a) the normal stresses induced in portions AB and BC by a temperature rise of 70°F, (b) the corresponding deflection of point B. SOLUTION AAB 4 (2.25) 2 3.9761 in 2 Free thermal expansion. ABC 4 (1.5)2 1.76715 in 2 T 70F (T) AB LAB a (T) (24)(13.3 106)(70) 22.344 103 in. (
T) BC LBC s (T) (32)(6.5 106)(70) 14.56 103 in. T (T) AB (T) BC 36.904 103 in. Total: Shortening due to induced compressive force P. PLAB 24 P 580.39 109 P Ea AAB (10.4 106)(3.9761) PLBC 32 P 624.42 109 P Es ABC (29 106)(1.76715) (P) AB (P) BC P (P) AB (P) BC 1204.81 109 P Total: For zero net deflection, P T (a)
1204.81 109 P 36.904 103 P 30.631 103 lb AB P 30.631 103 7.70 103 psi AAB 3.9761 AB 7.70 ksi BC P 30.631 103 17.33 103 psi ABC 1.76715 BC 17.33 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any
manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 151 PROBLEM 2.53 (Continued) (b) (P) AB (580.39 109)(30.631 103) 17.7779 103 in. B (T) AB (P) AB 22.344 103 17.7779 103 or B 4.57 103 in. (P) BC (624.42 109)(30.631 103) 19.1266 103 in. B (T
) BC (P) BC 14.56 103 19.1266 103 4.57 103 in. (checks) PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a
website, in whole or part. 152 PROBLEM 2.54 The steel rails of a railroad track (Es 200 GPa, αs 11.7 × 102–6/C) were laid at a temperature of 6C. Determine the normal stress in the rails when the temperature reaches 48C, assuming that the rails (a) are welded to form a continuous track, (b) are 10 m long with 3-mm gaps between them.
SOLUTION (a) T (T) L (11.7 106)(48 6)(10) 4.914 103 m P PL L (10) 50 1012 9 AE E 200 10 T P 4.914 103 50 1012 0 98.3 106 Pa (b) 98.3 MPa T P 4.914 103 50 1012 3 103 3 103 4.914 103 50 1012 38.3 106 Pa 38.3 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material
solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 153 PROBLEM 2.55 P⬘ 2m 15 mm Steel 5 mm Brass P Steel 40 mm Two steel bars (Es 200 GPa and s 11.7 106/ C) are used to reinforce
a brass bar (Eb 105 GPa, b 20.9 106/ C) that is subjected to a load P 25 kN. When the steel bars were fabricated, the distance between the centers of the holes that were to fit on the pins was made 0.5 mm smaller than the 2 m needed. The steel bars were then placed in an oven to increase their length so that they would just fit on the pins.
Following fabrication, the temperature in the steel bars dropped back to room temperature. Determine (a) the increase in temperature that was required to fit the steel bars on the pins, (b) the stress in the brass bar after the load is applied to it. SOLUTION (a) Required temperature change for fabrication: T 0.5 mm 0.5 103 m Temperature change
required to expand steel bar by this amount: T L s T , 0.5 103 (2.00)(11.7 106)(T), T 0.5 103 (2)(11.7 106)(T) T 21.368 C (b) 21.4 C * * Once assembled, a tensile force P develops in the steel, and a compressive force P develops in the brass, in order to elongate the steel and contract the brass. Elongation of steel: As (2)(5)(40) 400 mm 2 400
106 m 2 (P) s F *L P* (2.00) 25 109 P* As Es (400 106)(200 109) Contraction of brass: Ab (40)(15) 600 mm 2 600 106 m 2 (P)b P* L P* (2.00) 31.746 109 P* Ab Eb (600 106)(105 109) But (P) s (P)b is equal to the initial amount of misfit: (P) s (P)b 0.5 103 , 56.746 109 P* 0.5 103 P* 8.8112 103 N Stresses due to fabrication:
Steel: *s P * 8.8112 103 22.028 106 Pa 22.028 MPa 6 As 400 10 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on
a website, in whole or part. 154 PROBLEM 2.55 (Continued) Brass: b* P* 8.8112 103 14.6853 106 Pa 14.685 MPa 6 Ab 600 10 To these stresses must be added the stresses due to the 25-kN load. For the added load, the additional deformation is the same for both the steel and the brass. Let be the additional displacement. Also, let Ps and Pb be
the additional forces developed in the steel and brass, respectively. Ps L PL b As Es Ab Eb As Es (400 106)(200 109) 40 106 L 2.00 AE (600 106)(105 109) Pb b b 31.5 106 L 2.00 P Ps Pb 25 103 N Total: 40 106 31.5 106 25 103 349.65 106 m Ps (40 106)(349.65 106) 13.9860 103 N Pb (31.5 106)(349.65 10 6)
11.0140 103 N s Ps 13.9860 103 34.965 106 Pa 6 As 400 10 b Pb 11.0140 103 18.3566 106 Pa Ab 600 10 6 Add stress due to fabrication. Total stresses: s 34.965 106 22.028 106 56.991 106 Pa s 57.0 MPa b 18.3566 106 14.6853 106 3.6713 106 Pa b 3.67 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education.
This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 155 PROBLEM 2.56 P⬘ 2m 15 mm Steel 5 mm Brass P Steel 40 mm Determine the maximum load P that may be
applied to the brass bar of Prob. 2.55 if the allowable stress in the steel bars is 30 MPa and the allowable stress in the brass bar is 25 MPa. PROBLEM 2.55 Two steel bars (Es 200 GPa and s 11.7 10–6/C) are used to reinforce a brass bar (Eb 105 GPa, b 20.9 10–6/C) that is subjected to a load P 25 kN. When the steel bars were fabricated, the
distance between the centers of the holes that were to fit on the pins was made 0.5 mm smaller than the 2 m needed. The steel bars were then placed in an oven to increase their length so that they would just fit on the pins. Following fabrication, the temperature in the steel bars dropped back to room temperature. Determine (a) the increase in
temperature that was required to fit the steel bars on the pins, (b) the stress in the brass bar after the load is applied to it. SOLUTION See solution to Problem 2.55 to obtain the fabrication stresses. *s 22.028 MPa b* 14.6853 MPa Allowable stresses: s ,all 30 MPa, b,all 25 MPa Available stress increase from load. s 30 22.028 7.9720 MPa b 25
14.6853 39.685 MPa Corresponding available strains. s b s Es b Eb 7.9720 106 39.860 10 6 200 109 39.685 106 377.95 10 6 105 109 Smaller value governs 39.860 10 6 Areas: As (2)(5)(40) 400 mm 2 400 106 m 2 Ab (15)(40) 600 mm 2 600 106 m 2 Forces Ps Es As (200 109)(400 10 6)(39.860 10 6) 3.1888 103 N Pb Eb Ab (105
109)(600 106)(39.860 10 6) 2.5112 10 3 N Total allowable additional force: P Ps Pb 3.1888 103 2.5112 103 5.70 103 N P 5.70 kN PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may
not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 156 PROBLEM 2.57 Dimensions in mm 0.15 20 20 200 A An aluminum rod (Ea 70 GPa, αa 23.6 × 106/C) and a steel link (Es × 200 GPa, αa 11.7 × 106/C) have the dimensions shown at a temperature of 20C. The steel link is heated until the
aluminum rod can be fitted freely into the link. The temperature of the whole assembly is then raised to 150C. Determine the final normal stress (a) in the rod, (b) in the link. 30 A 20 Section A-A SOLUTION T T f Ti 150C 20C 130C Unrestrained thermal expansion of each part: Aluminum rod: (T)a L a (T) (T) a (0.200 m)(23.6 106 / C)(130C)
6.1360 10 4 m Steel link: (T) s L s (T) (T) s (0.200 m)(11.7 106 /C)(130C) 3.0420 10 4 m Let P be the compressive force developed in the aluminum rod. It is also the tensile force in the steel link. Aluminum rod: (P)a PL Ea Aa P (0.200 m) (70 10 Pa)(/4)(0.03 m)2 9 4.0420 109 P Steel link: (P) s PL Es As P (0.200) (200 109 Pa)(2)(0.02 m)2
1.250 109 P Setting the total deformed lengths in the link and rod equal gives (0.200) (T) s (P) s (0.200) (0.15 103) (T)a (P)a PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be
copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 157 PROBLEM 2.57 (Continued) (P) s (P)a 0.15 103 (T)a (T) s 1.25 109 P 4.0420 109 P 0.15 103 6.1360 104 3.0420 104 P 8.6810 104 N (a) Stress in rod: R P A 8.6810 104 N 1.22811 108 Pa 2 (/4)(0.030 m) R 122.8 MPa (b) Stress in link: L
8.6810 104 N 1.08513 108 Pa (2)(0.020 m)2 L 108.5 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a
website, in whole or part. 158 PROBLEM 2.58 0.02 in. 14 in. Bronze A 2.4 in2 E 15 106 psi 12 10 –6/F 18 in. Knowing that a 0.02-in. gap exists when the temperature is 75 F, determine (a) the temperature at which the normal stress in the aluminum bar will be equal to 11 ksi, (b) the corresponding exact length of the aluminum bar. Aluminum A
2.8 in2 E 10.6 106 psi 12.9 10 –6/F SOLUTION a 11 ksi 11 103 psi P a Aa (11 103)(2.8) 30.8 103 lb Shortening due to P: P PLb PLa Eb Ab Ea Aa (30.8 103)(14) (30.8 103)(18) (15 106)(2.4) (10.6 106)(2.8) 30.657 103 in. Available elongation for thermal expansion: T 0.02 30.657 103 50.657 103 in. But T Lb b (T) La a (T) (14)(12
106)(T) (18)(12.9 106)(T) (400.2 106)T Equating, (400.2 106)T 50.657 103 (a) (b) T 126.6F Thot Tcold T 75 126.6 201.6F a La a (T) Thot 201.6F PLa Ea Aa (18)(12.9 106)(26.6) (30.8 103)(18) 10.712 103 in. (10.6 106)(2.8) Lexact 18 10.712 103 18.0107 in. L 18.0107 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-
Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 159 PROBLEM 2.59 0.02 in. 14 in. 18 in. Determine (a) the compressive force in the bars shown
after a temperature rise of 180F, (b) the corresponding change in length of the bronze bar. Bronze A 2.4 in2 E 15 106 psi 12 10 –6/F Aluminum A 2.8 in2 E 10.6 106 psi 12.9 10 –6/F SOLUTION Thermal expansion if free of constraint: T Lb b (T) La a (T) (14)(12 106)(180) (18)(12.9 106)(180) 72.036 103 in. Constrained expansion: 0.02
in. Shortening due to induced compressive force P: P 72.036 103 0.02 52.036 103 in. P But PLb PLa Lb L a Eb Ab Ea Aa Eb Ab Ea Aa P 14 18 9 P 995.36 10 P 6 6 (15 10)(2.4) (10.6 10)(2.8) 995.36 109 P 52.036 103 Equating, P 52.279 103 lb P 52.3 kips (a) (b) b Lb b (T) PLb Eb Ab (14)(12 106)(180) (52.279 103)(14) 9.91
103 in. 6 (15 10)(2.4) b 9.91 103 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part.
160 PROBLEM 2.60 0.5 mm 300 mm At room temperature (20C) a 0.5-mm gap exists between the ends of the rods shown. At a later time when the temperature has reached 140C, determine (a) the normal stress in the aluminum rod, (b) the change in length of the aluminum rod. 250 mm A B Aluminum A 5 2000 mm2 E 5 75 GPa a 5 23 3 10–6/8C

Stainless steel A 5 800 mm2 E 5 190 GPa a 5 17.3 3 10–6/8C SOLUTION T 140 20 120C Free thermal expansion: T La a (T) Ls s (T) (0.300)(23 106)(120) (0.250)(17.3 106)(120) 1.347 103 m Shortening due to P to meet constraint: P 1.347 103 0.5 103 0.847 103 m PLa PLs La L s P Ea Aa Es As Ea Aa Es As 0.300 0.250 P 9 6 9 6
(75 10)(2000 10) (190 10)(800 10) 3.6447 109 P P 3.6447 109 P 0.847 103 Equating, P 232.39 103 N P 232.39 103 116.2 106 Pa Aa 2000 106 (a) a (b) a La a (T) a 116.2 MPa PLa Ea Aa (0.300)(23 106)(120) (232.39 103)(0.300) 363 106 m (75 109)(2000 106) a 0.363 mm PROPRIETARY MATERIAL. Copyright © 2015
McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 161 PROBLEM 2.61 P 5 8 5.0 in. in. diameter A standard tension test is used to
determine the properties of an experimental plastic. The test specimen is a 85 -in.-diameter rod and it is subjected to an 800-lb tensile force. Knowing that an elongation of 0.45 in. and a decrease in diameter of 0.025 in. are observed in a 5-in. gage length, determine the modulus of elasticity, the modulus of rigidity, and Poisson's ratio for the material.
P' SOLUTION A 4 d2 5 2 2 0.306796 in 4 8 P 800 lb y y x E y L x d 0.45 0.090 5.0 0.025 0.040 0.625 y 2.6076 103 28.973 103 psi 0.090 y v P 800 2.6076 103 psi A 0.306796 E 29.0 103 psi x 0.040 0.44444 0.090 y v 0.444 E 28.973 103 10.0291 103 psi 2(1 v) (2)(1 0.44444) 10.03 103 psi PROPRIETARY MATERIAL. Copyright ©
2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 162 PROBLEM 2.62 640 kN A 2-m length of an aluminum pipe of 240-mm outer
diameter and 10-mm wall thickness is used as a short column to carry a 640-kN centric axial load. Knowing that E 73 GPa and v 0.33, determine (a) the change in length of the pipe, (b) the change in its outer diameter, (c) the change in its wall thickness. 2m SOLUTION d o 0.240 t 0.010 L 2.0 di d o 2t 0.240 2(0.010) 0.220 m P 640 103 N A (a)
4 do2 di2 4 (0.240 0.220) 7.2257 103 m2 PL (640 103)(2.0) EA (73 109)(7.2257 103) 2.4267 103 m L 2.43 mm 2.4267 1.21335 103 2.0 LAT v (0.33)(1.21335 103) 4.0041 104 (b) d o d o LAT (240 mm)(4.0041 104) 9.6098 102 mm d o 0.0961 mm t t LAT (10 mm)(4.0041 104) 4.0041 103 mm t 0.00400 mm PROPRIETARY
MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 163 PROBLEM 2.63 200 kN 4 200 kN 10 200 mm 150
mm A line of slope 4:10 has been scribed on a cold-rolled yellow-brass plate, 150 mm wide and 6 mm thick. Knowing that E 105 GPa and v 0.34, determine the slope of the line when the plate is subjected to a 200-kN centric axial load as shown. SOLUTION A (0.150)(0.006) 0.9 103 m 2 x x P 200 103 222.22 106 Pa A 0.9 103 x E 222.22 106
2.1164 103 9 105 10 y x (0.34)(2.1164 103) 0.71958 103 tan 4(1 y) 10(1 x) 4(1 0.71958 103) 10(1 2.1164 103) 0.39887 tan 0.399 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This
document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 164 PROBLEM 2.64 50 mm 2.75 kN 2.75 kN A B 12 mm A 2.75-kN tensile load is applied to a test coupon made from 1.6-mm flat steel plate (E 200 GPa, v 0.30). Determine the resulting change (a) in the 50-mm gage length, (b) in the
width of portion AB of the test coupon, (c) in the thickness of portion AB, (d) in the crosssectional area of portion AB. SOLUTION A (1.6)(12) 19.20 mm 2 19.20 106 m 2 P 2.75 103 N x P 2.75 103 A 19.20 106 143.229 106 Pa x x E 143.229 106 716.15 106 9 200 10 y z x (0.30)(716.15 106) 214.84 106 (a) L 0.050 m x L x (0.50)
(716.15 106) 35.808 106 m 0.0358 mm (b) w 0.012 m y w y (0.012)(214.84 106) 2.5781 106 m 0.00258 mm (c) t 0.0016 m z t z (0.0016)(214.84 106) 343.74 109 m 0.000344 mm (d) A w0 (1 y)t0 (1 z) w0t0 (1 y z y z) A0 w0 t0 A A A0 w0t0 (y z negligible term) 2w0 t0 y (2)(0.012)(0.0016)(214.84 106) 8.25 109 m 2
0.00825 mm 2 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 165 PROBLEM 2.65 22-
mm diameter 75 kN 75 kN 200 mm In a standard tensile test, a steel rod of 22-mm diameter is subjected to a tension force of 75 kN. Knowing that v 0.3 and E 200 GPa, determine (a) the elongation of the rod in a 200-mm gage length, (b) the change in diameter of the rod. SOLUTION P 75 kN 75 103 N A x 4 d2 4 (0.022)2 380.13 106 m 2 P 75
103 197.301 106 Pa A 380.13 106 E 197.301 106 986.51 106 200 109 x L x (200 mm)(986.51 106) (a) x 0.1973 mm y v x (0.3)(986.51 106) 295.95 106 y d y (22 mm)(295.95 106) (b) y 0.00651 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor
use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 166 2.5 in. PROBLEM 2.66 The change in diameter of a large steel bolt is carefully measured as the nut is tightened. Knowing that E 29 106 psi and v 0.30, determine the
internal force in the bolt if the diameter is observed to decrease by 0.5 103 in. SOLUTION y 0.5 103 in. y y d v d 2.5 in. 0.5 103 0.2 103 2.5 y : x x y v 0.2 103 0.66667 103 0.3 x E x (29 106)(0.66667 103) 19.3334 103 psi A 4 d2 4 (2.5) 2 4.9087 in 2 F x A (19.3334 103)(4.9087) 94.902 103 lb F 94.9 kips PROPRIETARY
MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 167 PROBLEM 2.67 A The brass rod AD is fitted with a
jacket that is used to apply a hydrostatic pressure of 48 MPa to the 240-mm portion BC of the rod. Knowing that E 105 GPa and v 0.33, determine (a) the change in the total length AD, (b) the change in diameter at the middle of the rod. B 240 mm 600 mm C D 50 mm SOLUTION x z p 48 106 Pa, y 0 1 (x y z) E 1 48 106 (0.33)(0) (0.33)(48
106) 105 109 306.29 106 x 1 (x y z) E 1 (0.33)(48 106) 0 (0.33)(48 106) 105 109 301.71 106 y (a) Change in length: only portion BC is strained. L 240 mm y L y (240)(301.71 106) 0.0724 mm (b) Change in diameter: d 50 mm x z d x (50)(306.29 106) 0.01531 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill
Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 168 PROBLEM 2.68 y 4 in. 3 in. A B D z C z x x A fabric used in air-inflated structures is subjected to
a biaxial loading that results in normal stresses x 18 ksi and z 24 ksi . Knowing that the properties of the fabric can be approximated as E 12.6 × 106 psi and v 0.34, determine the change in length of (a) side AB, (b) side BC, (c) diagonal AC. SOLUTION x 18 ksi y 0 z 24 ksi 1 1 (x y z) 18,000 (0.34)(24, 000) 780.95 106 E 12.6 106 1 1 z (x
y z) (0.34)(18,000) 24,000 1.41905 103 6 E 12.6 10 x (a) AB (AB) x (4 in.)(780.95 106) 0.0031238 in. 0.00312 in. (b) BC (BC) z (3 in.)(1.41905 103) 0.0042572 in. 0.00426 in. Label sides of right triangle ABC as a, b, c. Then c2 a 2 b2 Obtain differentials by calculus. 2cdc 2ada 2bdb dc But a 4 in. b 3 in. da AB 0.0031238 in. (c) 4
5 a b da db c c c 42 32 5 in. db BC 0.0042572 in. 3 5 AC dc (0.0031238) (0.0042572) 0.00505 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated,
forwarded, distributed, or posted on a website, in whole or part. 169 PROBLEM 2.69 y 6 ksi A B x 12 ksi 1 in. A 1-in. square was scribed on the side of a large steel pressure vessel. After pressurization the biaxial stress condition at the square is as shown. Knowing that E 29 × 106 psi and v 0.30, determine the change in length of (a) side AB, (b)
side BC, (c) diagonal AC. C D 1 in. SOLUTION 1 1 (x y) E 29 106 6 351.72 10 1 1 y (y x) E 29 106 82.759 106 x 12 103 (0.30)(6 103) 6 103 (0.30)(12 103) (a) AB (AB)0 x (1.00)(351.72 106) 352 106 in. (b) BC (BC)0 y (1.00)(82.759 106) 82.8 106 in. (c) (AC) (AB) 2 (BC) 2 (AB0 x)2 (BC0 y)2 (1 351.72 106)2 (1
82.759 106) 2 1.41452 AC (AC)0 307 106 (AC)0 2 or use calculus as follows: Label sides using a, b, and c as shown. c2 a 2 b2 Obtain differentials. dc from which 2cdc 2ada 2bdc a b da dc c c But a 100 in., b 1.00 in., c 2 in. da AB 351.72 106 in., db BC 82.8 106 in. AC dc 1.00 2 (351.7 106) 1.00 2 (82.8 106) 307 106 in.
PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 170 PROBLEM 2.70 The block shown is
made of a magnesium alloy, for which E 45 GPa and v 0.35. Knowing that x 180 MPa, determine (a) the magnitude of y for which the change in the height of the block will be zero, (b) the corresponding change in the area of the face ABCD, (c) the corresponding change in the volume of the block. SOLUTION (a) y 0 y 0 z 0 1 (x v y v z) E y v x
(0.35)(180 106) y y 63.0 MPa 63 106 Pa 1 v (0.35)(243 106) (z v x v y) (x y) 1.890 103 E E 45 109 x v y 1 157.95 106 x (x v y v Z) 3.510 103 E E 45 109 z (b) A0 Lx Lz A Lx (1 x) Lz (1 z) Lx Lz (1 x z x z) A A A0 Lx Lz (x z x z) Lx Lz (x z) A (100 mm)(25 mm)(3.510 103 1.890 103) (c) A 4.05 mm 2 V0 Lx Ly
Lz V Lx (1 x) Ly (1 y) Lz (1 z) Lx Ly Lz (1 x y z x y y z z x x y z) V V V0 Lx Ly Lz (x y z small terms) V (100)(40)(25)(3.510 103 0 1.890 103) V 162.0 mm3 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or
distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 171 PROBLEM 2.71 y A B D z C z x x The homogeneous plate ABCD is subjected to a biaxial loading as shown. It is known that z 0 and that the change in length of the plate in the x direction must be
zero, that is, x 0. Denoting by E the modulus of elasticity and by v Poisson's ratio, determine (a) the required magnitude of x , (b) the ratio 0 / z . SOLUTION z 0 , y 0, x 0 x 1 1 (x v y v z) (x v 0) E E x v 0 (a) (b) z 1 1 1 v2 (v x v y z) (v 2 0 0 0) 0 E E E 0 E z 1 v2 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill
Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 172 y P' PROBLEM 2.72 P x x P A z (a) P' ' ' 45□ m P x For a member under axial loading, express
the normal strain in a direction forming an angle of 45 with the axis of the load in terms of the axial strain x by (a) comparing the hypotenuses of the triangles shown in Fig. 2.43, which represent, respectively, an element before and after deformation, (b) using the values of the corresponding stresses of and x shown in Fig. 1.38, and the generalized
Hooke's law. P m 2A ' ' P 2A (b) SOLUTION Figure 2.49 (a) [2(1)]2 (1 x)2 (1 v x)2 2(1 2 2) 1 2 x x2 1 2v x v 2 x2 4 2 2 2 x x2 2v x v 2 x2 4 2 x 2v x Neglect squares as small. (A) 1 v x 2 (B) PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not
authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 173 PROBLEM 2.72 (Continued) (b) v E E 1 v P E 2A 1 v x 2E 1 v x 2 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely
for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 174 y PROBLEM 2.73 x In many situations, it is known that the normal stress in a given direction is zero. For example, z 0 in the case of the thin
plate shown. For this case, which is known as plane stress, show that if the strains x and y have been determined experimentally, we can express x , y , and z as follows: x E x v y 1 v 2 y E y v x 1 v 2 z v (x y) 1 v SOLUTION z 0 x 1 (x v y) E (1) y 1 (v x y) E (2) Multiplying (2) by v and adding to (1), x v y 1 v2 x E or x E (x v y) 1 v2 or y
E (y v x) 1 v2 Multiplying (1) by v and adding to (2), y v x 1 v2 y E 1 v E (v x v y) (x v y y v x) E E 1 v2 v(1 v) v (x y) (x y) 2 1 v 1 v z PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This
document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 175 PROBLEM 2.74 y y x x z (a) z In many situations, physical constraints prevent strain from occurring in a given direction. For example, z 0 in the case shown, where longitudinal movement of the long prism is prevented at every
point. Plane sections perpendicular to the longitudinal axis remain plane and the same distance apart. Show that for this situation, which is known as plane strain, we can express z , x , and y as follows: z v(x y) (b) 1 [(1 v 2) x v(1 v) y] E 1 y [(1 v 2) y v(1 v) x] E x SOLUTION z 0 1 (v x v y z) or z v(x y) E 1 (x v y v z) E 1 [x v y v 2
(x y)] E 1 [(1 v 2) x v(1 v) y] E x 1 (v x y v z) E 1 [v x y v 2 (x y)] E 1 [(1 v 2) y v(1 v) x] E y PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned,
duplicated, forwarded, distributed, or posted on a website, in whole or part. 176 PROBLEM 2.75 3.2 in. The plastic block shown is bonded to a rigid support and to a vertical plate to which a 55-kip load P is applied. Knowing that for the plastic used G 150 ksi, determine the deflection of the plate. 4.8 in. P 2 in. SOLUTION A (3.2)(4.8) 15.36 in 2 P
55 103 lb P 55 103 3580.7 psi A 15.36 G 150 103 psi G h 2 in. 3580.7 23.871 103 150 103 h (2)(23.871 103) 47.7 103 in. 0.0477 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This
document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 177 PROBLEM 2.76 3.2 in. What load P should be applied to the plate of Prob. 2.75 to produce a deflection? 1 -in. 16 PROBLEM 2.75 The plastic block shown is bonded to a rigid support and to a vertical plate to which a 55-kip load P is
applied. Knowing that for the plastic used G 150 ksi, determine the deflection of the plate. 4.8 in. 2 in. P SOLUTION 1 in. 0.0625 in. 16 h 2 in. h 0.0625 0.03125 2 G 150 103 psi G (150 103)(0.03125) 4687.5 psi A (3.2)(4.8) 15.36 in 2 P A (4687.5)(15.36) 72.0 103 lb 72.0 kips PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill
Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 178 b PROBLEM 2.77 a a Two blocks of rubber with a modulus of rigidity G 12 MPa are bonded to
rigid supports and to a plate AB. Knowing that c 100 mm and P 45 kN, determine the smallest allowable dimensions a and b of the blocks if the shearing stress in the rubber is not to exceed 1.4 MPa and the deflection of the plate is to be at least 5 mm. B A P c SOLUTION Shearing strain: a Shearing stress: b a G 1 2 P A G (12 106 Pa)(0.005 m)
0.0429 m 1.4 106 Pa P 2bc 45 103 N P 0.1607 m 2c 2(0.1 m)(1.4 106 Pa) a 42.9 mm b 160.7 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated,
forwarded, distributed, or posted on a website, in whole or part. 179 b PROBLEM 2.78 a a Two blocks of rubber with a modulus of rigidity G 10 MPa are bonded to rigid supports and to a plate AB. Knowing that b 200 mm and c 125 mm, determine the largest allowable load P and the smallest allowable thickness a of the blocks if the shearing stress
in the rubber is not to exceed 1.5 MPa and the deflection of the plate is to be at least 6 mm. B A P c SOLUTION Shearing stress: 1 2 P A P 2bc P 2bc 2(0.2 m)(0.125 m)(1.5 103 kPa) Shearing strain: a a G P 75.0 kN G (10 106 Pa)(0.006 m) 0.04 m 1.5 106 Pa a 40.0 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education.
This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 180 PROBLEM 2.79 An elastomeric bearing (G 130 psi) is used to support a bridge girder as shown to provide
flexibility during earthquakes. The beam must not displace more than 83 in. when a 5-kip lateral load is applied as shown. Knowing that the maximum allowable shearing stress is 60 psi, determine (a) the smallest allowable dimension b, (b) the smallest required thickness a. P a b 8 in. SOLUTION Shearing force: P 5 kips 5000 lb Shearing stress: 60
psi and (a) b (b) P , A or A P 5000 83.333 in 2 60 A (8 in.)(b) A 83.333 10.4166 in. 8 8 b 10.42 in. 60 461.54 103 rad 130 0.375 in. But , or a a 461.54 103 a 0.813 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or
distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 181 PROBLEM 2.80 For the elastomeric bearing in Prob. 2.79 with b 10 in. and a 1 in., determine the shearing modulus G and the shear stress for a maximum lateral load P 5 kips and a maximum
displacement 0.4 in. P a b 8 in. SOLUTION Shearing force: P 5 kips 5000 lb Area: A (8 in.)(10 in.) 80 in 2 Shearing stress: Shearing strain: Shearing modulus: G a P 5000 80 A 62.5 psi 0.4 in. 0.400 rad 1 in. 62.5 0.400 G 156.3 psi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for
authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 182 PROBLEM 2.81 P A 150 mm 100 mm A vibration isolation unit consists of two blocks of hard rubber bonded to a plate AB and to rigid supports as
shown. Knowing that a force of magnitude P 25 kN causes a deflection 1.5 mm of plate AB, determine the modulus of rigidity of the rubber used. B 30 mm 30 mm SOLUTION F 1 1 P (25 103 N) 12.5 103 N 2 2 F (12.5 103 N) 833.33 103 Pa A (0.15 m)(0.1 m) 1.5 103 m h 0.03 m 1.5 103 0.05 h 0.03 833.33 103 G 16.67 106 Pa 0.05 G
16.67 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 183 PROBLEM 2.82 P A 150
mm 100 mm A vibration isolation unit consists of two blocks of hard rubber with a modulus of rigidity G 19 MPa bonded to a plate AB and to rigid supports as shown. Denoting by P the magnitude of the force applied to the plate and by the corresponding deflection, determine the effective spring constant, k P/ , of the system. B 30 mm 30 mm
SOLUTION Shearing strain: Shearing stress: G h G h GA 1 P A h 2 Force: P P k with A (0.15)(0.1) 0.015 m 2 k 2GA h 2GA h Effective spring constant: or h 0.03 m 2(19 106 Pa)(0.015 m 2) 19.00 106 N/m 0.03 m k 19.00 103 kN/m PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for
authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 184 PROBLEM 2.83 A 6-in.-diameter solid steel sphere is lowered into the ocean to a point where the pressure is 7.1 ksi (about 3 miles below the
surface). Knowing that E 29 106 psi and v 0.30, determine (a) the decrease in diameter of the sphere, (b) the decrease in volume of the sphere, (c) the percent increase in the density of the sphere. SOLUTION For a solid sphere, V0 6 d 03 (6.00)3 6 113.097 in 3 x y z p 7.1 103 psi 1 (x v y v z) E (1 2v) p (0.4)(7.1 103) E 29 106 x 97.93 106
Likewise, y z 97.93 106 e x y z 293.79 106 (a) d d 0 x (6.00)(97.93 106) 588 106 in. (b) V V0 e (113.097)(293.79 106) 33.2 103 in 3 (c) Let m mass of sphere. d 588 106 in. V 33.2 103 in 3 m constant. m 0V0 V V0 (1 e) 0 V 1 m 1 0 1 1 1 e 0 0 V0 (1 e) m (1 e e 2 e3) 1 e e 2 e3 e 293.79 106 0 100% (293.79 106)
(100%) 0 0.0294% PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 185 PROBLEM 2.84
85 mm (a) For the axial loading shown, determine the change in height and the change in volume of the brass cylinder shown. (b) Solve part a, assuming that the loading is hydrostatic with x y z 70 MPa. sy 5 258 MPa E 5 105 GPa n 5 0.33 135 mm SOLUTION h0 135 mm 0.135 m A 0 d 02 (85) 2 5.6745 103 mm 2 5.6745 103 m 2 4 4 V0 A0
h0 766.06 103 mm3 766.06 106 m3 (a) x 0, y 58 106 Pa, z 0 y y 1 58 106 (v x y v z) 552.38 106 9 E E 105 10 h h 0 y (135 mm)(552.38 106) e h 0.0746 mm (1 2v) y (0.34)(58 106) 1 2v (x y z) 187.81 106 9 E E 105 10 V V0 e (766.06 103 mm3)(187.81 106) (b) x y z 70 106 Pa y V 143.9 mm3 x y z 210 106 Pa 1 1
2v (0.34)(70 106) (v x y v z) y 226.67 106 E E 105 109 h h 0 y (135 mm)(226.67 106) e h 0.0306 mm 1 2v (0.34)(210 106) (x y z) 680 106 E 105 109 V V0 e (766.06 103 mm3)(680 106) V 521 mm3 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor
use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 186 PROBLEM 2.85* 1 in. diameter 11 kips 11 kips Determine the dilatation e and the change in volume of the 8-in. length of the rod shown if (a) the rod is made of steel
with E 29 × 106 psi and v 0.30, (b) the rod is made of aluminum with E 10.6 × 106 psi and v 0.35. 8 in. SOLUTION A d2 4 4 3 P 11 10 lb Stresses : (a) Steel. (1) 2 0.78540 in 2 P 11 103 14.0056 103 psi A 0.78540 y z 0 x E 29 106 psi x y z v 0.30 1 14.0056 103 (x v y v z) x 482.95 106 E E 29 106 v 1 (v x y v z) x v x (0.30)(482.95
106) E E 144.885 106 v 1 (v x v y z) x y 144.885 106 E E e x y z 193.2 106 v ve Le (0.78540)(8)(193.2 106) 1.214 103 in 3 (b) Aluminum. E 10.6 106 psi x x E v 0.35 14.0056 103 1.32128 103 10.6 106 y v x (0.35)(1.32128 103) 462.45 106 z y 462.45 106 e x y z 396 106 v ve Le (0.78540)(8)(396 106) 2.49 103 in
3 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 187 PROBLEM 2.86 Determine the
change in volume of the 50-mm gage length segment AB in Prob. 2.64 (a) by computing the dilatation of the material, (b) by subtracting the original volume of portion AB from its final volume. PROBLEM 2.64 A 2.75-kN tensile load is applied to a test coupon made from 1.6-mm flat steel plate (E 200 GPa, v 0.30). Determine the resulting change (a) in
the 50-mm gage length, (b) in the width of portion AB of the test coupon, (c) in the thickness of portion AB, (d) in the cross-sectional area of portion AB. 50 mm 2.75 kN 2.75 kN A B 12 mm SOLUTION (a) A0 (12)(1.6) 19.2 mm 2 19.2 106 m 2 Volume V0 L0 A0 (50)(19.2) 960 mm3 x P 2.75 103 143.229 106 Pa A0 19.2 106 x 1 143.229 106 (x
y z) x 716.15 106 E E 200 109 y z 0 y z x (0.30)(716.15 103) 214.84 106 e x y z 286.46 106 v v0 e (960)(286.46 106) 0.275 mm3 (b) From the solution to problem 2.64, x 0.035808 mm y 0.0025781 z 0.00034374 mm The dimensions when under the 2.75-kN load are Length: L L0 x 50 0.035808 50.035808 mm Width: w w0
y 12 0.0025781 11.997422 mm Thickness: t t0 z 1.6 0.00034374 1.599656 mm Volume: V Lwt (50.03581)(11.997422)(1.599656) 960.275 mm3 V V V0 960.275 960 0.275 mm3 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or
distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 188 PROBLEM 2.87 P A vibration isolation support consists of a rod A of radius R1 10 mm and a tube B of inner radius R 2 25 mm bonded to an 80-mm-long hollow rubber cylinder with a modulus of
rigidity G 12 MPa. Determine the largest allowable force P that can be applied to rod A if its deflection is not to exceed 2.50 mm. R1 A R2 80 mm B SOLUTION Let r be a radial coordinate. Over the hollow rubber cylinder, R1 r R2 . Shearing stress acting on a cylindrical surface of radius r is The shearing strain is P P A 2 rh G P 2 Ghr Shearing
deformation over radial length dr: d dr d dr P dr 2 Gh r Total deformation. R2 R1 d P 2 Gh R2 P ln r R1 2 Gh R P ln 2 R1 2 Gh Data: R1 10 mm 0.010 m, R2 R2 25 mm 0.025 m, h 80 mm 0.080 m G 12 106 Pa P dr R1 r P (ln R2 ln R1) 2 Gh 2 Gh or P ln(R2 / R1) 2.50 103 m (2)(12 106) (0.080) (2.50 10 3) 16.46 103 N ln (0.025/0.010)
16.46 kN PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 189 PROBLEM 2.88 P A A
vibration isolation support consists of a rod A of radius R1 and a tube B of inner radius R2 bonded to a 80-mm-long hollow rubber cylinder with a modulus of rigidity G 10.93 MPa. Determine the required value of the ratio R2/R1 if a 10-kN force P is to cause a 2-mm deflection of rod A. R1 R2 80 mm B SOLUTION Let r be a radial coordinate. Over the
hollow rubber cylinder, R1 r R2 . Shearing stress acting on a cylindrical surface of radius r is P P A 2 rh The shearing strain is G P 2 Ghr Shearing deformation over radial length dr: d dr d dr dr P dr 2 Gh r Total deformation. R2 R1 d P 2 Gh R2 P ln r R1 2 Gh R P ln 2 R1 2 Gh ln dr r P (ln R2 ln R1) 2 Gh R2 R1 R2 2 Gh (2) (10.93 106)
(0.080) (0.002) 1.0988 R1 P 10.103 R2 exp (1.0988) 3.00 R1 R2 /R1 3.00 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or
posted on a website, in whole or part. 190 PROBLEM 2.89 The material constants E, G, k, and v are related by Eqs. (2.33) and (2.43). Show that any one of these constants may be expressed in terms of any other two constants. For example, show that (a) k GE/(9G 3E) and (b) v (3k 2G)/(6k 2G). SOLUTION k (a) 1 v and G E 2(1 v) E E 1 or v 2G 2G
k (b) E 3(1 2v) 2 EG 2 EG E E 3[2G 2 E 4G] 18G 6 E 3 1 2 1 2G k EG 9G 6 E v 3k 2G 6k 2G k 2(1 v) G 3(1 2v) 3k 6kv 2G 2Gv 3k 2G 2G 6k PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This
document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 191 PROBLEM 2.90 Show that for any given material, the ratio G/E of the modulus of rigidity over the modulus of elasticity is always less than 12 but more than 13 . [Hint: Refer to Eq. (2.43) and to Sec. 2.13.] SOLUTION G E 2(1 v)
Assume v 0 for almost all materials, and v PY; therefore, mild steel yields. P1 force carried by mild steel Let P2 force carried by tempered steel P1 A1 Y 1 (1.00)(50 103) 50 103 lb P1 P2 P, P2 P P1 98 103 50 103 48 103 lb 2 Unloading. P2 48 103 64 103 psi A2 0.75 P 98 103 56 103 psi A 1.75 Residual stresses. Mild steel: 1,res 1
50 103 56 103 6 103 psi 6 ksi Tempered steel: 2,res 2 1 64 103 56 103 8 103 psi 8.00 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated,
forwarded, distributed, or posted on a website, in whole or part. 229 PROBLEM 2.120 P' 3 16 1 2 in. 3 16 in. in. 14 in. For the composite bar in Prob. 2.111, determine the residual stresses in the tempered-steel bars if P is gradually increased from zero until the deformation of the bar reaches a maximum value m 0.04 in. and is then decreased back
to zero. PROBLEM 2.111 Two tempered-steel bars, each 163 in. thick, are bonded to a 12 -in. mild-steel bar. This composite bar is subjected as shown to a centric axial load of magnitude P. Both steels are elastoplastic with E 29 106 psi and with yield strengths equal to 100 ksi and 50 ksi, respectively, for the tempered and mild steel. The load P is
gradually increased from zero until the deformation of the bar reaches a maximum value m 0.04 in. and then decreased back to zero. Determine (a) the maximum value of P, (b) the maximum stress in the tempered-steel bars, (c) the permanent set after the load is removed. 2.0 in. P SOLUTION L (14)(50 103) 1 A1 (2) 1.00 in 2 Y 1 Y 1 0.024138
in. E 29 106 2 For the mild steel, L (14)(100 103) 3 For the tempered steel, A2 2 (2) 0.75 in 2 Y 2 Y 2 0.048276 in. E 29 106 16 A A1 A2 1.75 in 2 Total area: Y 1 m Y 2 The mild steel yields. Tempered steel is elastic. P1 A1Y 1 (1.00)(50 103) 50 103 lb Forces: P2 Stresses: 1 EA2 m (29 106)(0.75)(0.04) 62.14 103 lb L 14 P1 P 62.14
103 Y 1 50 103 psi 2 2 82.86 103 psi A1 A2 0.75 Unloading: P 112.14 64.08 103 psi A 1.75 Residual stresses. 1,res 1 50 103 64.08 103 14.08 103 psi 14.08 ksi 2,res 2 82.86 103 64.08 103 18.78 103 psi 18.78 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for
authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 230 PROBLEM 2.121 Narrow bars of aluminum are bonded to the two sides of a thick steel plate as shown. Initially, at T1 70F, all stresses are zero.
Knowing that the temperature will be slowly raised to T2 and then reduced to T1, determine (a) the highest temperature T2 that does not result in residual stresses, (b) the temperature T2 that will result in a residual stress in the aluminum equal to 58 ksi. Assume a 12.8 106 / F for the aluminum and s 6.5 106 / F for the steel. Further assume that
the aluminum is elastoplastic, with E 10.9 106 psi and Y 58 ksi. (Hint: Neglect the small stresses in the plate.) SOLUTION Determine temperature change to cause yielding. PL L a (T)Y L s (T)Y EA P E (a s)(T)Y Y A Y 58 103 (T)Y 844.62F E (a s) (10.9 106)(12.8 6.5)(106) (a) T2Y T1 (T)Y 70 844.62 915F 915F After yielding, Y L E
L a (T) L s (T) AE The residual stress is res Y Set res Y Y Y E (a s)(T) T (b) P Y E (a s)(T) A 2 Y (2)(58 103) 1689F E (a s) (10.9 106)(12.8 6.5)(106) T2 T1 T 70 1689 1759F 1759F If T2 1759F, the aluminum bar will most likely yield in compression. PROPRIETARY MATERIAL. Copyright © 2015
McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 231 A C B F a 120 mm 440 mm PROBLEM 2.122 Bar AB has a cross-sectional area of
1200 mm2 and is made of a steel that is assumed to be elastoplastic with E 200 GPa and Y 250 MPa. Knowing that the force F increases from 0 to 520 kN and then decreases to zero, determine (a) the permanent deflection of point C, (b) the residual stress in the bar. SOLUTION A 1200 mm 2 1200 106 m 2 Force to yield portion AC: PAC A Y
(1200 106)(250 106) 300 103 N For equilibrium, F PCB PAC 0. PCB PAC F 300 103 520 103 220 103 N C PCB LCB (220 103)(0.440 0.120) EA (200 109)(1200 106) 0.29333 103 m PCB 220 103 A 1200 106 183.333 106 Pa CB PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely
for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 232 PROBLEM 2.122 (Continued) Unloading: C LAC) LCB PAC P L (F PAC CB CB EA EA EA L FL L AC BC CB PAC EA EA EA PAC
FLCB (520 103)(0.440 0.120) 378.18 103 N 0.440 LAC LCB PAC F 378.18 103 520 103 141.820 103 N PCB PAC 378.18 103 315.150 106 Pa 6 A 1200 10 P 141.820 103 BC 118.183 106 Pa BC 6 A 1200 10 (378.18 103)(0.120) 0.189090 103 m C (200 109)(1200 106) AC (a) C , p C C 0.29333 10 3 0.189090 10 3
0.104240 10 3 m 0.1042 mm (b) AC , res Y AC 250 106 315.150 106 65.150 106 Pa 65.2 MPa CB, res CB CB 183.333 106 118.183 106 65.150 106 Pa 65.2 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or
distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 233 PROBLEM 2.123 A C B F a 120 mm 440 mm Solve Prob. 2.122, assuming that a 180 mm. PROBLEM 2.122 Bar AB has a cross-sectional area of 1200 mm2 and is made of a steel that is assumed to
be elastoplastic with E 200 GPa and Y 250 MPa. Knowing that the force F increases from 0 to 520 kN and then decreases to zero, determine (a) the permanent deflection of point C, (b) the residual stress in the bar. SOLUTION A 1200 mm 2 1200 106 m 2 Force to yield portion AC: PAC A Y (1200 106)(250 106) 300 103 N For equilibrium, F
PCB PAC 0. PCB PAC F 300 103 520 103 220 103 N C PCB LCB (220 103)(0.440 0.180) EA (200 109)(1200 106) 0.23833 103 m PCB 220 103 A 1200 106 183.333 106 Pa CB PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale
or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 234 PROBLEM 2.123 (Continued) Unloading: LAC) LCB PAC P L (F PAC CB CB EA EA EA L FL L AC BC CB PAC EA EA EA C PAC FLCB (520 103)(0.440 0.180) 307.27 103 N LAC LCB
0.440 PAC F 307.27 103 520 103 212.73 103 N PCB C (307.27 103)(0.180) 0.23045 103 m 6 9 (200 10)(1200 10) PAC 307.27 103 256.058 106 Pa A 1200 106 P 212.73 103 CB 177.275 106 Pa CB A 1200 106 AC (a) C , p C C 0.23833 10 3 0.23045 10 3 0.00788 10 3 m 0.00788 mm (b) AC ,res AC AC 250 106 256.058
106 6.0580 106 Pa 6.06 MPa CB,res CB CB 183.333 106 177.275 106 6.0580 106 Pa 6.06 MPa PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned,
duplicated, forwarded, distributed, or posted on a website, in whole or part. 235 PROBLEM 2.124 l The uniform wire ABC, of unstretched length 2l, is attached to the supports shown and a vertical load P is applied at the midpoint B. Denoting by A the cross-sectional area of the wire and by E the modulus of elasticity, show that, for l , the deflection
at the midpoint B is l A C B P l3 P AE SOLUTION Use approximation. sin tan Statics: l FY 0 : 2 PAB sin P 0 PAB Elongation: P Pl 2sin 2 AB PAB l Pl 2 AE 2 AE Deflection: From the right triangle, (l AB) 2 l 2 2 2 2 l 2 2l AB AB l2 1 AB 2l AB 1 2 l 3 2l AB Pl 3 AE Pl 3 P l3 AE AE PROPRIETARY MATERIAL. Copyright © 2015
McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 236 28 kips PROBLEM 2.125 28 kips The aluminum rod ABC (E 10.1 106 psi), which
consists of two cylindrical portions AB and BC, is to be replaced with a cylindrical steel rod DE (E 29 106 psi) of the same overall length. Determine the minimum required diameter d of the steel rod if its vertical deformation is not to exceed the deformation of the aluminum rod under the same load and if the allowable stress in the steel rod is not to
exceed 24 ksi. D A 1.5 in. 12 in. B 2.25 in. d 18 in. C E SOLUTION Deformation of aluminum rod. A PLAB PLBC AAB E ABC E P LAB LBC E AAB ABC 28 103 12 10.1 106 4 (1.5)2 0.031376 in. Steel rod. 18 (2.25) 2 4 0.031376 in. PL PL (28 103)(30) A 0.92317 in 2 EA E (29 106)(0.031376) P A A P 28 103 1.16667 in 2 3 24 10
Required area is the larger value. A 1.16667 in 2 Diameter: d 4A (4)(1.16667) d 1.219 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded,
distributed, or posted on a website, in whole or part. 237 PROBLEM 2.126 C Two solid cylindrical rods are joined at B and loaded as shown. Rod AB is made of steel (E 29 106 psi), and rod BC of brass (E 15 106 psi). Determine (a) the total deformation of the composite rod ABC, (b) the deflection of point B. 3 in. 30 in. B 30 kips 30 kips 2 in. 40 in.
A P 40 kips SOLUTION Portion AB: PAB 40 103 lb LAB 40 in. d 2 in. E AB AB Portion BC: d2 (2)2 3.1416 in 2 4 4 29 106 psi AAB PAB LAB (40 103)(40) 17.5619 103 in. E AB AAB (29 106)(3.1416) PBC 20 103 lb LBC 30 in. d 3 in. EBC BC d2 (3) 2 7.0686 in 2 4 4 15 106 psi ABC PBC LBC (20 103)(30) 5.6588 103 in. EBC ABC
(15 106)(7.0686) (a) AB BC 17.5619 106 5.6588 106 11.90 103 in. (b) B BC B 5.66 103 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated,
forwarded, distributed, or posted on a website, in whole or part. 238 Brass strip: E 5 105 GPa a 5 20 3 1026/8C PROBLEM 2.127 100 kg A 40 mm 3 mm 20 mm The brass strip AB has been attached to a fixed support at A and rests on a rough support at B. Knowing that the coefficient of friction is 0.60 between the strip and the support at B, determine
the decrease in temperature for which slipping will impend. B SOLUTION Brass strip: E 105 GPa 20 106 / C Fy 0 : N W 0 N W Fx 0 : P N 0 Data: PL L (T) 0 EA P W mg T mg P EA EA 0.60 A (20)(3) 60 mm 2 60 106 m 2 m 100 kg g 9.81 m/s 2 E 105 109 Pa T (0.60)(100)(9.81) (105 109)(60 106)(20 106) T 4.67C PROPRIETARY
MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 239 P' 112 -in. diameter A 1-in. diameter B 112 -in.
diameter C 2 in. D 3 in. P PROBLEM 2.128 The specimen shown is made from a 1-in.-diameter cylindrical steel rod with two 1.5-in.-outer-diameter sleeves bonded to the rod as shown. Knowing that E 29 106 psi, determine (a) the load P so that the total deformation is 0.002 in., (b) the corresponding deformation of the central portion BC. 2 in.
SOLUTION (a) Pi Li P Li Ai Ei E Ai 1 L P E i Ai di2 4 Ai L, in. d, in. A, in2 L/A, in1 AB 2 1.5 1.7671 1.1318 BC 3 1.0 0.7854 3.8197 CD 2 1.5 1.7671 1.1318 6.083 P (29 106)(0.002)(6.083) 1 9.353 103 lb (b) BC PLBC P LBC 9.535 103 (3.8197) ABC E E ABC 29 106 sum P 9.53 kips 1.254 103 in. PROPRIETARY MATERIAL. Copyright ©
2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 240 PROBLEM 2.129 250 mm Each of the four vertical links connecting the two
rigid horizontal members is made of aluminum (E 70 GPa) and has a uniform rectangular cross section of 10 40 mm. For the loading shown, determine the deflection of (a) point E, (b) point F, (c) point G. 400 mm A 250 mm B 40 mm C D E 300 mm F G 24 kN SOLUTION Statics. Free body EFG: M F 0 : (400)(2 FBE) (250)(24) 0 FBE 7.5 kN 7.5
103 N M E 0 : (400)(2 FCF) (650)(24) 0 FCF 19.5 kN 19.5 103 N Area of one link: A (10)(40) 400 mm 2 400 106 m 2 Length: L 300 mm 0.300 m Deformations. BE FBE L (7.5 103)(0.300) 80.357 106 m 6 9 EA (70 10)(400 10) CF FCF L (19.5 103)(0.300) 208.93 106 m EA (70 109)(400 106) PROPRIETARY MATERIAL. Copyright ©
2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 241 PROBLEM 2.129 (Continued) (a) Deflection of Point E. E | BF | E 80.4 m
(b) Deflection of Point F. F CF F 209 m Geometry change. Let be the small change in slope angle. (c) E F LEF Deflection of Point G. 80.357 106 208.93 106 723.22 106 radians 0.400 G F LFG G F LFG 208.93 106 (0.250)(723.22 106) 389.73 106 m G 390 m PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education.
This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 242 PROBLEM 2.130 P A 4-ft concrete post is reinforced with four steel bars, each with a 34 -in. diameter.
Knowing that Es 29 106 psi and Ec 3.6 106 psi, determine the normal stresses in the steel and in the concrete when a 150-kip axial centric force P is applied to the post. 4 ft 8 in. 8 in. SOLUTION 3 2 As 4 1.76715 in 2 4 4 Ac 82 As 62.233 in 2 s Ps L Ps (48) 0.93663 106 Ps As Es (1.76715)(29 106) c Pc L Pc (48) 0.21425 106 Pc Ac Ec
(62.233)(3.6 106) But s c : 0.93663 106 Ps 0.21425 106 Pc Ps 0.22875Pc Also, Substituting (1) into (2), (1) Ps Pc P 150 kips (2) 1.22875Pc 150 kips Pc 122.075 kips From (1), Ps 0.22875(122.075) 27.925 kips s Ps 27.925 1.76715 As s 15.80 ksi c Pc 122.075 62.233 Ac c 1.962 ksi PROPRIETARY MATERIAL. Copyright © 2015 McGraw-
Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 243 PROBLEM 2.131 A The steel rods BE and CD each have a 16-mm diameter (E 200 GPa); the
ends of the rods are single-threaded with a pitch of 2.5 mm. Knowing that after being snugly fitted, the nut at C is tightened one full turn, determine (a) the tension in rod CD, (b) the deflection of point C of the rigid member ABC. 150 mm B 100 mm D E C 2m 3m SOLUTION Let be the rotation of bar ABC as shown. Then B 0.15 But C turn PCD
C 0.25 PCD LCD ECD ACD ECD ACD (turn C) LCD (200 109 Pa) 4 (0.016 m) 2 2m (0.0025 m 0.25) 50.265 103 5.0265 106 B PBE PBE LBE EBE ABE or PBE EBE ABE B LBE (200 109 Pa) 4 (0.016 m)2 3m (0.15) 2.0106 106 From free body of member ABC: M A 0 : 0.15 PBE 0.25 PCD 0 0.15(2.0106 106) 0.25(50.265 103 5.0265 106) 0
8.0645 103 rad (a) PCD 50.265 103 5.0265 106 (8.0645 103) 9.7288 103 N (b) PCD 9.73 kN C 0.25 0.25(8.0645 103) 2.0161 103 m C 2.02 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This
document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 244 PROBLEM 2.132 8 in. Aluminum shell 1.25 in. 0.75 in. Steel core The assembly shown consists of an aluminum shell (Ea 10.6 106 psi, a 12.9 106/°F) fully bonded to a steel core (Es 29 106 psi, s 6.5 106/°F) and is unstressed.
Determine (a) the largest allowable change in temperature if the stress in the aluminum shell is not to exceed 6 ksi, (b) the corresponding change in length of the assembly. SOLUTION Since a s , the shell is in compression for a positive temperature rise. a 6 ksi 6 103 psi Let Aa As d 4 4 2 o di2 d2 4 4 (1.252 0.752) 0.78540 in 2 (0.75) 2
0.44179 in 2 P a Aa s As where P is the tensile force in the steel core. s (a s)(T) (6.4 106)(T) (a) T 145.91F (b) a Aa s Es s Es As (6 103)(0.78540) 10.667 103 psi 0.44179 s (T) a Ea a (T) a Ea 10.667 103 6 103 0.93385 103 6 6 29 10 10.6 10 T 145.9F 10.667 103 (6.5 106)(145.91) 1.3163 103 6 29 10 or 6 103 (12.9 106)
(145.91) 1.3163 103 6 10.6 10 L (8.0)(1.3163 103) 0.01053 in. 0.01053 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed,
or posted on a website, in whole or part. 245 PROBLEM 2.133 3.5 in. P 5.5 in. The plastic block shown is bonded to a fixed base and to a horizontal rigid plate to which a force P is applied. Knowing that for the plastic used G 55 ksi, determine the deflection of the plate when P 9 kips. 2.2 in. SOLUTION Consider the plastic block. The shearing force
carried is P 9 103 lb The area is A (3.5)(5.5) 19.25 in 2 Shearing stress: Shearing strain: But P 9 103 467.52 psi A 19.25 G h 467.52 0.0085006 55 103 h (2.2)(0.0085006) 0.01870 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for
sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 246 PROBLEM 2.134 P 150 75 15 300 60 r56 150 The aluminum test specimen shown is subjected to two equal and opposite centric axial forces of magnitude P. (a) Knowing that E 70 GPa and
all 200 MPa, determine the maximum allowable value of P and the corresponding total elongation of the specimen. (b) Solve part a, assuming that the specimen has been replaced by an aluminum bar of the same length and a uniform 60 15-mm rectangular cross section. 75 P' Dimensions in mm SOLUTION all 200 106 Pa E 70 109 Pa Amin (60
mm)(15 mm) 900 mm 2 900 106 m 2 (a) Test specimen. D 75 mm, d 60 mm, r 6 mm D 75 1.25 d 60 From Fig. 2.60b, K 1.95 P r 6 0.10 d 60 max K P A A max (900 106) (200 106) 92.308 103 N K 1.95 P 92.3 kN Wide area A* (75 mm)(15 mm) 1125 mm 2 1.125 103 m 2 Pi Li P L 92.308 103 i Ai Ei E Ai 70 109 0.300 0.150 0.150
1.125 103 900 106 1.125 103 7.91 106 m (b) 0.791 mm Uniform bar. P A all (900 106)(200 106) 180 103 N (180 103)(0.600) PL 1.714 103 m AE (900 106)(70 109) P 180.0 kN 1.714 mm PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not
authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 247 PROBLEM 2.135 L B C B' k m C' P P The uniform rod BC has a cross-sectional area A and is made of a mild steel that can be assumed to be elastoplastic with a modulus of
elasticity E and a yield strength Y . Using the block-and-spring system shown, it is desired to simulate the deflection of end C of the rod as the axial force P is gradually applied and removed, that is, the deflection of points C and C should be the same for all values of P. Denoting by the coefficient of friction between the block and the horizontal
surface, derive an expression for (a) the required mass m of the block, (b) the required constant k of the spring. SOLUTION Force-deflection diagram for Point C or rod BC. P PY A Y For PL EA PY A Y C Pmax EA C L P Force-deflection diagram for Point C of block-and-spring system. Fy 0 : N mg 0 N mg Fx 0 : P F f 0 P Ff If block does not move,
i.e., F f N mg or c then P K P mg , or P k c If P mg, then slip at P Fm mg occurs. If the force P is the removed, the spring returns to its initial length. (a) Equating PY and Fmax, (b) Equating slopes, A Y mg k m EA L A Y g PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized
instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 248 PROBLEM 2.C1 A rod consisting of n elements, each of which is homogeneous and of uniform cross section, is subjected to the loading shown. The length of
element i is denoted by Li , its cross-sectional area by Ai , modulus of elasticity by Ei , and the load applied to its right end by Pi , the magnitude Pi of this load being assumed to be positive if Pi is directed to the right and negative otherwise. (a) Write a computer program that can be used to determine the average normal stress in each element, the
deformation of each element, and the total deformation of the rod. (b) Use this program to solve Probs. 2.20 and 2.126. Element 1 Element n P1 Pn SOLUTION For each element, enter Li , Ai , Ei Compute deformation P P Pi Update axial load Compute for each element i P/ Ai i PLi / Ai Ei Total deformation: Update through n elements i Program
Outputs Problem 2.20 Element Stress (MPa) Deformation (mm) 1 19.0986 0.1091 2 12.7324 0.0909 Total Deformation 0.0182 mm Problem 2.126 Element Stress (ksi) Deformation (in.) 1 12.7324 0.0176 2 2.8294 0.0057 Total Deformation 0.01190 in. PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material
solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 249 PROBLEM 2.C2 A Element n Element 1 B Pn P2 Rod AB is horizontal with both ends fixed; it consists of n elements, each of which is
homogeneous and of uniform cross section, and is subjected to the loading shown. The length of element i is denoted by Li , its crosssectional area by Ai , its modulus of elasticity by Ei , and the load applied to its right end by Pi , the magnitude Pi of this load being assumed to be positive if Pi is directed to the right and negative otherwise. (Note that
P1 0.) (a) Write a computer program which can be used to determine the reactions at A and B, the average normal stress in each element, and the deformation of each element. (b) Use this program to solve Probs. 2.41 and 2.42. SOLUTION We Consider the reaction at B redundant and release the rod at B Compute B with RB 0 For each element,
enter Li , Ai , Ei Update axial load P P Pi Compute for each element i P/Ai i PLi /Ai Ei Update total deformation B B i Compute B due to unit load at B Unit i 1/Ai Unit i Li /Ai Ei Update total unit deformation Unit B Unit B Unit i Superposition B0 For total displacement at B RB Unit B 0 Solving: RB B /Unit B Then: RA Pi RB
PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 250 PROBLEM 2.C2 (Continued) For
each element i RB Unit i i RB Unit i Program Outputs Problem 2.41 RA 62.809 kN RB 37.191 kN Element Stress (MPa) Deformation (mm) 1 52.615 0.05011 2 3.974 0.00378 3 2.235 0.00134 4 49.982 0.04498 Problem 2.42 RA 45.479 kN RB 54.521 kN Element Stress (MPa) Deformation (mm) 1 77.131 0.03857 2 20.542 0.01027 3 11.555
0.01321 4 36.191 0.06204 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 251
PROBLEM 2.C3 Element n Element 1 A 0 B Rod AB consists of n elements, each of which is homogeneous and of uniform cross section. End A is fixed, while initially there is a gap 0 between end B and the fixed vertical surface on the right. The length of element i is denoted by Li , its cross-sectional area by Ai , its modulus of elasticity by Ei , and its
coefficient of thermal expansion by i . After the temperature of the rod has been increased by T , the gap at B is closed and the vertical surfaces exert equal and opposite forces on the rod. (a) Write a computer program which can be used to determine the magnitude of the reactions at A and B, the normal stress in each element, and the deformation
of each element. (b) Use this program to solve Probs. 2.59 and 2.60. SOLUTION We compute the displacements at B. Assuming there is no support at B, enter Li , Ai , Ei , i Enter temperature change T. Compute for each element. i i LiT Update total deformation. B B i Compute B due to unit load at B. Unit i Li /Ai Ei Update total unit
deformation. Unit B Unit B Unit i Compute reactions. From superposition, RB (B 0)/Unit B Then RA RB For each element, i RB /Ai i LiT RB Li /Ai Ei PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner.
This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole or part. 252 PROBLEM 2.C3 (Continued) Program Outputs Problem 2.59. R 52.279 kips Stress (ksi) Deformation (10 * 3 in.) 1 21.783 9.909 2 18.671 10.091 Element Problem 2.60. R 232.390 kN Element Stress (MPa) Deformation
(microm) 1 116.195 363.220 2 290.487 136.780 PROPRIETARY MATERIAL. Copyright © 2015 McGraw-Hill Education. This is proprietary material solely for authorized instructor use. Not authorized for sale or distribution in any manner. This document may not be copied, scanned, duplicated, forwarded, distributed, or posted on a website, in whole
or part. 253 PROBLEM 2.C4 A 1, E1, (Y)1 L P A 2 , E2 , (Y)2 Plate Bar AB has a length L and is made of two different materials of given cross-sectional area, modulus of elasticity, and yield strength. The bar is subjected as shown to a load P that is gradually increased from zero until the deformation of the bar has reached a maximum value m and
then decreased back to zero. (a) Write a computer program that, for each of 25 values of m equally spaced over a range extending from 0 to a value equal to 120% of the deformation causing both materials to yield, can be used to determine the maximum value Pm of the load, the maximum normal stress in each material, the permanent deformation
p of the bar, and the residual stress in each material. (b) Use this program to solve Probs. 2.111 and 2.112. SOLUTION (Y)1 < (Y)2 Note: The following assumes Displacement increment m 0.05(Y) 2 L/E2 Displacements at yielding A (Y)1 L/E1 B (Y) 2 L/E2 For each displacement If m < A: 1 m E1/L 2 m E2 /L Pm (m /L) (A1E1 A2 E2) If
A

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