Table 6.1, determine the force that will produce an elastic reduction of 4×10^{-3} mm in the diameter.

6.17 A cylindrical specimen of an alloy 8 mm in diameter is stressed elastically in tension. A force of 15,700 N produces a reduction in specimen diameter of 5×10^{-3} mm. Compute Poisson's ratio for this material if its modulus of elasticity is 140 GPa.

6.18 A cylindrical specimen of a hypothetical metal alloy is stressed in compression. If its original and final diameters are 20.000 and 20.025 mm, respectively, and its final length is 74.96 mm, compute its original length if the deformation is totally elastic. The elastic and shear moduli for this alloy are 105 GPa and 39.7 GPa, respectively.

6.19 Consider a cylindrical specimen of some hypothetical metal alloy that has a diameter of 8.0 mm. A tensile force of 1000 N produces an elastic reduction in diameter of 2.8×10^{-4} mm. Compute the modulus of elasticity for this alloy, given that Poisson's ratio is 0.30.

6.20 A brass alloy is known to have a yield strength of 275 MPa, a tensile strength of 380 MPa, and an elastic modulus of 103 GPa. A cylindrical specimen of this alloy 12.7 mm in diameter and 250 mm long is stressed in tension and found to elongate 7.6 mm. On the basis of the information given, is it possible to compute the magnitude of the load that is necessary to produce this change in length? If so, calculate the load. If not, explain why.

6.21 A cylindrical metal specimen 12.9 mm in diameter and 260 mm long is to be subjected to a tensile stress of 28 MPa; at this stress level the resulting deformation will be totally elastic.

(a) If the elongation must be less than 0.080 mm, which of the metals in Table 6.1 are suitable candidates? Why?

(b) If, in addition, the maximum permissible diameter decrease is 1.2×10^{-3} mm when the tensile stress of 28 MPa is applied, which of the metals that satisfy the criterion in part (a) are suitable candidates? Why?

6.22 Consider the brass alloy for which the stress–strain behavior is shown in Figure 6.12. A cylindrical specimen of this material 8 mm in diameter and 60 mm long is pulled in tension with a force of 5000 N. If it is known that this alloy has a Poisson's ratio of 0.30, compute **(a)** the specimen elongation and **(b)** the reduction in specimen diameter.

6.23 A cylindrical rod 100 mm long and having a diameter of 10.0 mm is to be deformed using a tensile load of 27,500 N. It must not experience either plastic deformation or a diameter reduction of more than 7.5×10^{-3} mm. Of the materials listed as follows, which are possible candidates? Justify your choice(s).

Material	*Modulus of Elasticity (GPa)*	*Yield Strength (MPa)*	*Poisson's Ratio*
Aluminum alloy	70	200	0.33
Brass alloy	101	300	0.34
Steel alloy	207	400	0.30
Titanium alloy	107	650	0.34

6.24 A cylindrical rod 380 mm long, having a diameter of 10.0 mm, is to be subjected to a tensile load. If the rod is to experience neither plastic deformation nor an elongation of more than 0.9 mm when the applied load is 24,500 N, which of the four metals or alloys listed in the following table are possible candidates? Justify your choice(s).

Material	*Modulus of Elasticity (GPa)*	*Yield Strength (MPa)*	*Tensile Strength (MPa)*
Aluminum alloy	70	255	420
Brass alloy	100	345	420
Copper	110	250	290
Steel alloy	207	450	550

Tensile Properties

6.25 Figure 6.21 shows the tensile engineering stress–strain behavior for a steel alloy.

(a) What is the modulus of elasticity?

(b) What is the proportional limit?

(c) What is the yield strength at a strain offset of 0.002?

(d) What is the tensile strength?

6.26 A cylindrical specimen of a brass alloy having a length of 60 mm must elongate only 10.8 mm when a tensile load of 50,000 N is applied. Under these circumstances, what must be the radius of the specimen? Consider this brass alloy to have the stress–strain behavior shown in Figure 6.12.

6.27 A load of 85,000 N is applied to a cylindrical specimen of a steel alloy (displaying the stress–strain behavior shown in Figure 6.21) that has a cross-sectional diameter of 20 mm.

(a) Will the specimen experience elastic and/or plastic deformation? Why?

(b) If the original specimen length is 260 mm, how much will it increase in length when this load is applied?

6.28 A bar of a steel alloy that exhibits the stress–strain behavior shown in Figure 6.21 is subjected to a tensile load; the specimen is 310 mm long and has a square cross section 4.8 mm on a side.

(a) Compute the magnitude of the load necessary to produce an elongation of 0.48 mm.

(b) What will be the deformation after the load has been released?

6.29 A cylindrical specimen of aluminum having a diameter of 12.8 mm and a gauge length of 50.800 mm is pulled in tension. Use the load–elongation characteristics shown in the following table to complete parts (a) through (f).

Load	***Length***
N	***mm***
0	50.800
7,330	50.851
15,100	50.902
23,100	50.952
30,400	51.003
34,400	51.054
38,400	51.308
41,300	51.816
44,800	52.832
46,200	53.848
47,300	54.864
47,500	55.880
46,100	56.896
44,800	57.658
42,600	58.420
36,400	59.182
Fracture	

(a) Plot the data as engineering stress versus engineering strain.

(b) Compute the modulus of elasticity.

(c) Determine the yield strength at a strain offset of 0.002.

(d) Determine the tensile strength of this alloy.

(e) What is the approximate ductility, in percent elongation?

(f) Compute the modulus of resilience.

6.30 A specimen of ductile cast iron having a rectangular cross section of dimensions 4.8 mm × 15.9 mm is deformed in tension. Using the load–elongation data shown in the following table, complete parts (a) through (f).

Load	***Length***
N	***mm***
0	75.000
4,740	75.025
9,140	75.050
12,920	75.075
16,540	75.113
18,300	75.150
20,170	75.225
22,900	75.375
25,070	75.525
26,800	75.750
28,640	76.500
30,240	78.000
31,100	79.500
31,280	81.000
30,820	82.500
29,180	84.000
27,190	85.500
24,140	87.000
18,970	88.725
Fracture	

(a) Plot the data as engineering stress versus engineering strain.

(b) Compute the modulus of elasticity.

(c) Determine the yield strength at a strain offset of 0.002.

(d) Determine the tensile strength of this alloy.

(e) Compute the modulus of resilience.

(f) What is the ductility, in percent elongation?

6.31 For the titanium alloy, whose stress-strain behavior may be observed in the "Tensile Tests" module of *Virtual Materials Science and Engineering* (*VMSE*), determine the following:

Metal Alloys

(a) the approximate yield strength (0.002 strain offset),

(b) the tensile strength, and

(c) the approximate ductility, in percent elongation.

How do these values compare with those for the two Ti-6A1-4V alloys presented in Table B.4 of Appendix B?

6.32 For the tempered steel alloy, whose stress-strain behavior may be observed in the "Tensile Tests" module of *Virtual Materials Science and Engineering* (*VMSE*), determine the following:

Metal Alloys

(a) the approximate yield strength (0.002 strain offset),

(b) the tensile strength, and

(c) the approximate ductility, in percent elongation.

How do these values compare with those for the oil-quenched and tempered 4140 and 4340 steel alloys presented in Table B.4 of Appendix B?

6.33 For the aluminum alloy, whose stress-strain behavior may be observed in the "Tensile Tests" module of *Virtual Materials Science and Engineering* (*VMSE*), determine the following:

Metal Alloys

(a) the approximate yield strength (0.002 strain offset),

(b) the tensile strength, and

(c) the approximate ductility, in percent elongation.

How do these values compare with those for the 2024 aluminum alloy (T351 temper) presented in Table B.4 of Appendix B?

6.34 For the (plain) carbon steel alloy, whose stress-strain behavior may be observed in the "Tensile Tests" module of *Virtual Materials Science and Engineering* (*VMSE*), determine the following:

Metal Alloys

(a) the approximate yield strength,

(b) the tensile strength, and

(c) the approximate ductility, in percent elongation.

6.35 A cylindrical metal specimen having an original diameter of 12.9 mm and gauge length of 50.90 mm is pulled in tension until fracture occurs. The diameter at the point of fracture is 6.70 mm, and the fractured gauge length is 72.14 mm. Calculate the ductility in terms of percent reduction in area and percent elongation.

6.36 Calculate the moduli of resilience for the materials having the stress–strain behaviors shown in Figures 6.12 and 6.21.

6.37 Determine the modulus of resilience for each of the following alloys:

Material	*Yield Strength* *MPa*
Steel alloy	550
Brass alloy	350
Aluminum alloy	250
Titanium alloy	800

Use the modulus of elasticity values in Table 6.1.

6.38 A brass alloy to be used for a spring application must have a modulus of resilience of at least 0.80 MPa. What must be its minimum yield strength?

True Stress and Strain

6.39 Show that Equations 6.18a and 6.18b are valid when there is no volume change during deformation.

6.40 Demonstrate that Equation 6.16, the expression defining true strain, may also be represented by

$$\epsilon_T = \ln\left(\frac{A_0}{A_i}\right)$$

when specimen volume remains constant during deformation. Which of these two expressions is more valid during necking? Why?

6.41 Using the data in Problem 6.29 and Equations 6.15, 6.16, and 6.18a, generate a true stress–true strain plot for aluminum. Equation 6.18a becomes invalid past the point at which necking begins; therefore, measured diameters are given in the following table for the last four data points, which should be used in true stress computations.

Load	*Length*	*Diameter*
N	*mm*	*mm*
46,100	56.896	11.71
42,400	57.658	10.95
42,600	58.420	10.62
36,400	59.182	9.40

6.42 A tensile test is performed on a metal specimen, and it is found that a true plastic strain of 0.20 is produced when a true stress of 575 MPa is applied; for the same metal, the value of K in Equation 6.19 is 860 MPa. Calculate the true strain that results from the application of a true stress of 600 MPa.

6.43 For some metal alloy, a true stress of 415 MPa produces a plastic true strain of 0.475. How much will a specimen of this material elongate when a true stress of 325 MPa is applied if the original length is 300 mm? Assume a value of 0.25 for the strain-hardening exponent n.

6.44 The following true stresses produce the corresponding true plastic strains for a brass alloy:

True Stress (MPa)	*True Strain*
345	0.10
415	0.20

What true stress is necessary to produce a true plastic strain of 0.25?

6.45 For a brass alloy, the following engineering stresses produce the corresponding plastic engineering strains, prior to necking:

Engineering Stress (MPa)	*Engineering Strain*
235	0.194
250	0.296

On the basis of this information, compute the *engineering* stress necessary to produce an *engineering* strain of 0.25.

6.46 Find the toughness (or energy to cause fracture) for a metal that experiences both elastic and plastic deformation. Assume Equation 6.5 for elastic deformation, that the modulus of elasticity is 172 GPa, and that elastic deformation terminates at a strain of 0.01. For plastic deformation, assume that the relationship between stress and strain is described by Equation 6.19, in which the values for K and n are 6900 MPa and 0.30, respectively. Furthermore, plastic deformation occurs between strain values of 0.01 and 0.75, at which point fracture occurs.

6.47 For a tensile test, it can be demonstrated that necking begins when

$$\frac{d\sigma_T}{d\epsilon_T} = \sigma_T \tag{6.26}$$

Using Equation 6.19, determine the value of the true strain at this onset of necking.

6.48 Taking the logarithm of both sides of Equation 6.19 yields

$$\log \sigma_T = \log K + n \log \epsilon_T \tag{6.27}$$

Thus, a plot of $\log \sigma_T$ versus $\log \epsilon_T$ in the plastic region to the point of necking should yield a straight line having a slope of n and an intercept (at $\log \sigma_T = 0$) of $\log K$.

Using the appropriate data tabulated in Problem 6.29, make a plot of $\log \sigma_T$ versus $\log \epsilon_T$ and determine the values of n and K. It will be necessary to convert engineering stresses and strains to true stresses and strains using Equations 6.18a and 6.18b.

Elastic Recovery after Plastic Deformation

6.49 A cylindrical specimen of a brass alloy 7.8 mm in diameter and 95.0 mm long is pulled in tension with a force of 6000 N; the force is subsequently released.

(a) Compute the final length of the specimen at this time. The tensile stress–strain behavior for this alloy is shown in Figure 6.12.

(b) Compute the final specimen length when the load is increased to 16,500 N and then released.

6.50 A steel alloy specimen having a rectangular cross section of dimensions 12.7 mm × 6.4 mm has the stress–strain behavior shown in Figure 6.21. If this specimen is subjected to a tensile force of 38,000 N, then

(a) Determine the elastic and plastic strain values.