Chapter 2

2-1 From Table A-20

$$S_{ut} = 470\,\text{MPa (68 kpsi)}, \quad S_y = 390\,\text{MPa (57 kpsi)} \quad \textit{Ans.}$$

2-2 From Table A-20

$$S_{ut} = 620\,\text{MPa (90 kpsi)}, \quad S_y = 340\,\text{MPa (49.5 kpsi)} \quad \textit{Ans.}$$

2-3 Comparison of yield strengths:

$$S_{ut} \text{ of G10 500 HR is } \frac{620}{470} = 1.32 \text{ times larger than SAE1020 CD} \quad \textit{Ans.}$$

$$S_{yt} \text{ of SAE1020 CD is } \frac{390}{340} = 1.15 \text{ times larger than G10500 HR} \quad \textit{Ans.}$$

From Table A-20, the ductilities (reduction in areas) show,

$$\text{SAE1020 CD is } \frac{40}{35} = 1.14 \text{ times larger than G10500} \quad \textit{Ans.}$$

The stiffness values of these materials are identical *Ans.*

	S_{ut} MPa (kpsi)	S_y MPa (kpsi)	Table A-20 Ductility $R\%$	Table A-5 Stiffness GPa (Mpsi)
SAE1020 CD	470(68)	390 (57)	40	207(30)
UNS10500 HR	620(90)	340(495)	35	207(30)

2-4 From Table A-21

$$\text{1040 Q\&T} \quad \bar{S}_y = 593\,(86)\ \text{MPa (kpsi)} \quad \text{at } 205^\circ\text{C } (400^\circ\text{F}) \quad \textit{Ans.}$$

2-5 From Table A-21

$$\text{1040 Q\&T} \quad R = 65\% \quad \text{at } 650^\circ\text{C } (1200^\circ\text{F}) \quad \textit{Ans.}$$

2-6 Using Table A-5, the specific strengths are:

$$\text{UNS G10350 HR steel:} \quad \frac{S_y}{W} = \frac{39.5(10^3)}{0.282} = 1.40(10^5)\text{ in} \quad \textit{Ans.}$$

$$\text{2024 T4 aluminum:} \quad \frac{S_y}{W} = \frac{43(10^3)}{0.098} = 4.39(10^5)\text{ in} \quad \textit{Ans.}$$

$$\text{Ti-6Al-4V titanium:} \quad \frac{S_y}{W} = \frac{140(10^3)}{0.16} = 8.75(10^5)\text{ in} \quad \textit{Ans.}$$

ASTM 30 gray cast iron has no yield strength. *Ans.*

2-7 The specific moduli are:

$$\text{UNS G10350 HR steel:} \quad \frac{E}{W} = \frac{30(10^6)}{0.282} = 1.06(10^8)\ \text{in} \quad \textit{Ans.}$$

$$\text{2024 T4 aluminum:} \quad \frac{E}{W} = \frac{10.3(10^6)}{0.098} = 1.05(10^8)\ \text{in} \quad \textit{Ans.}$$

$$\text{Ti-6Al-4V titanium:} \quad \frac{E}{W} = \frac{16.5(10^6)}{0.16} = 1.03(10^8)\ \text{in} \quad \textit{Ans.}$$

$$\text{Gray cast iron:} \quad \frac{E}{W} = \frac{14.5(10^6)}{0.26} = 5.58(10^7)\ \text{in} \quad \textit{Ans.}$$

2-8

$$2G(1+\nu) = E \quad \Rightarrow \quad \nu = \frac{E - 2G}{2G}$$

From Table A-5

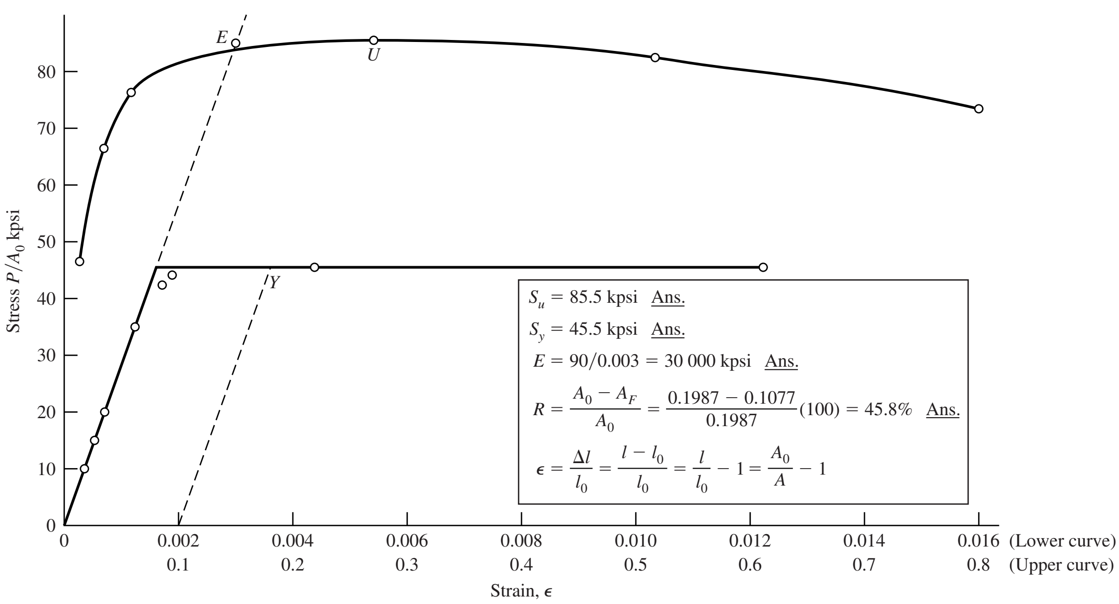
$$\text{Steel:} \quad \nu = \frac{30 - 2(11.5)}{2(11.5)} = 0.304 \quad \textit{Ans.}$$

$$\text{Aluminum:} \quad \nu = \frac{10.4 - 2(3.90)}{2(3.90)} = 0.333 \quad \textit{Ans.}$$

$$\text{Beryllium copper:} \quad \nu = \frac{18 - 2(7)}{2(7)} = 0.286 \quad \textit{Ans.}$$

$$\text{Gray cast iron:} \quad \nu = \frac{14.5 - 2(6)}{2(6)} = 0.208 \quad \textit{Ans.}$$

2-9



2-10 To plot σ_{true} vs. ε, the following equations are applied to the data.

$$A_0 = \frac{\pi(0.503)^2}{4} = 0.1987\ \text{in}^2$$

Eq. (2-4) $$\varepsilon = \ln\frac{l}{l_0} \quad \text{for} \quad 0 \le \Delta L \le 0.0028\ \text{in}$$

$$\varepsilon = \ln\frac{A_0}{A} \quad \text{for} \quad \Delta L > 0.0028\ \text{in}$$

$$\sigma_{true} = \frac{P}{A}$$

The results are summarized in the table below and plotted on the next page.
The last 5 points of data are used to plot $\log\sigma$ vs $\log\varepsilon$

The curve fit gives $m = 0.2306$

$$\log\sigma_0 = 5.1852 \quad \Rightarrow \quad \sigma_0 = 153.2\ \text{kpsi} \qquad \textit{Ans.}$$

For 20% cold work, Eq. (2-10) and Eq. (2-13) give,

$$A = A_0(1 - W) = 0.1987(1 - 0.2) = 0.1590\ \text{in}^2$$

$$\varepsilon = \ln\frac{A_0}{A} = \ln\frac{0.1987}{0.1590} = 0.2231$$

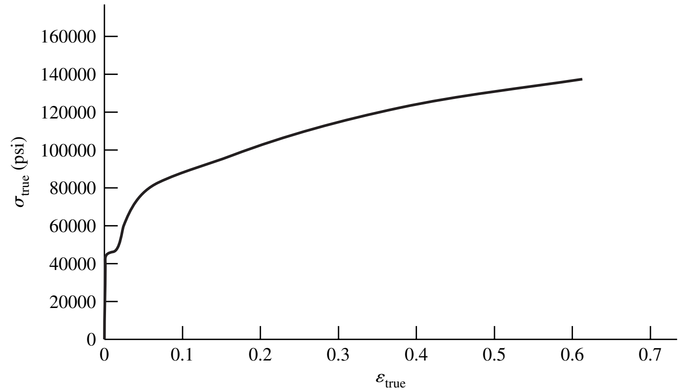
Eq. (2-14):

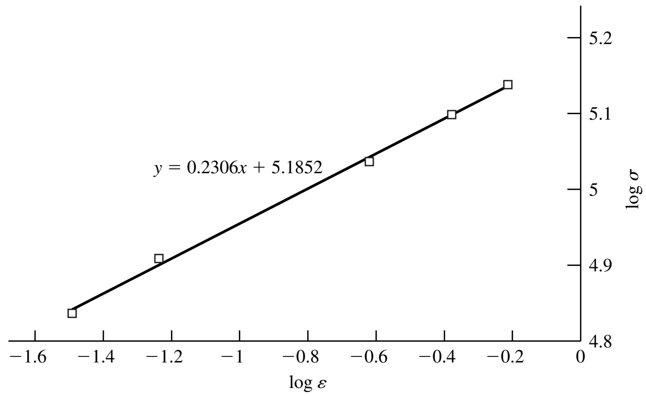
$$S'_y = \sigma_0\varepsilon^m = 153.2(0.2231)^{0.2306} = 108.4\ \text{kpsi} \qquad \textit{Ans.}$$

Eq. (2-15), with $S_u = 85.5$ kpsi from Prob. 2-9,

$$S'_u = \frac{S_u}{1 - W} = \frac{85.5}{1 - 0.2} = 106.9\ \text{kpsi} \qquad \textit{Ans.}$$

P	ΔL	A	ε	σ_{true}	$\log\varepsilon$	$\log\sigma_{true}$
0	0	0.198 713	0	0		
1 000	0.0004	0.198 713	0.000 2	5032.388	−3.699 01	3.701 774
2 000	0.0006	0.198 713	0.000 3	10 064.78	−3.522 94	4.002 804
3 000	0.0010	0.198 713	0.000 5	15 097.17	−3.301 14	4.178 895
4 000	0.0013	0.198 713	0.000 65	20 129.55	−3.187 23	4.303 834
7 000	0.0023	0.198 713	0.001 149	35 226.72	−2.939 55	4.546 872
8 400	0.0028	0.198 713	0.001 399	42 272.06	−2.854 18	4.626 053
8 800	0.0036	0.198 4	0.001 575	44 354.84	−2.802 61	4.646 941
9 200	0.0089	0.197 8	0.004 604	46 511.63	−2.336 85	4.667 562
9 100		0.196 3	0.012 216	46 357.62	−1.913 05	4.666 121
13 200		0.192 4	0.032 284	68 607.07	−1.491 01	4.836 369
15 200		0.187 5	0.058 082	81 066.67	−1.235 96	4.908 842
17 000		0.156 3	0.240 083	108 765.2	−0.619 64	5.036 49
16 400		0.130 7	0.418 956	125 478.2	−0.377 83	5.098 568
14 800		0.107 7	0.612 511	137 418.8	−0.212 89	5.138 046





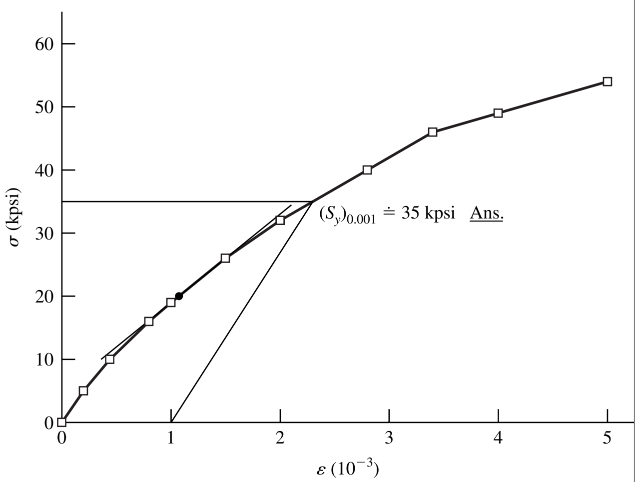
2-11 Tangent modulus at $\sigma = 0$ is

$$E_0 = \frac{\Delta\sigma}{\Delta\varepsilon} \doteq \frac{5000 - 0}{0.2(10^{-3}) - 0} = 25(10^6)\text{ psi}$$

At $\sigma = 20$ kpsi

$$E_{20} \doteq \frac{(26 - 19)(10^3)}{(1.5 - 1)(10^{-3})} = 14.0(10^6)\text{ psi} \quad \textit{Ans.}$$

$\varepsilon(10^{-3})$	σ (kpsi)
0	0
0.20	5
0.44	10
0.80	16
1.0	19
1.5	26
2.0	32
2.8	40
3.4	46
4.0	49
5.0	54



2-12 Since $|\varepsilon_o| = |\varepsilon_i|$

$$\left|\ln\frac{R+h}{R+N}\right| = \left|\ln\frac{R}{R+N}\right| = \left|-\ln\frac{R+N}{R}\right|$$

$$\frac{R+h}{R+N} = \frac{R+N}{R}$$

$$(R+N)^2 = R(R+h)$$

From which, $$N^2 + 2RN - Rh = 0$$

The roots are: $$N = R\left[-1 \pm \left(1+\frac{h}{R}\right)^{1/2}\right]$$

The + sign being significant,

$$N = R\left[\left(1+\frac{h}{R}\right)^{1/2} - 1\right] \quad Ans.$$

Substitute for N in

$$\varepsilon_o = \ln\frac{R+h}{R+N}$$

Gives $$\varepsilon_0 = \ln\left[\frac{R+h}{R + R\left(1+\frac{h}{R}\right)^{1/2} - R}\right] = \ln\left(1+\frac{h}{R}\right)^{1/2} \quad Ans.$$

These constitute a useful pair of equations in cold-forming situations, allowing the surface strains to be found so that cold-working strength enhancement can be estimated.

2-13 From Table A-22

AISI 1212 $$S_y = 28.0 \text{ kpsi}, \quad \sigma_f = 106 \text{ kpsi}, \quad S_{ut} = 61.5 \text{ kpsi}$$

$$\sigma_0 = 110 \text{ kpsi}, \quad m = 0.24, \quad \varepsilon_f = 0.85$$

From Eq. (2-12) $$\varepsilon_u = m = 0.24$$

Eq. (2-10) $$\frac{A_0}{A_i'} = \frac{1}{1-W} = \frac{1}{1-0.2} = 1.25$$

Eq. (2-13) $$\varepsilon_i = \ln 1.25 = 0.2231 \quad \Rightarrow \quad \varepsilon_i < \varepsilon_u$$

Eq. (2-14) $$S_y' = \sigma_0 \varepsilon_i^m = 110(0.2231)^{0.24} = 76.7 \text{ kpsi} \quad Ans.$$

Eq. (2-15) $$S_u' = \frac{S_u}{1-W} = \frac{61.5}{1-0.2} = 76.9 \text{ kpsi} \quad Ans.$$

2-14 For $H_B = 250$,

Eq. (2-17) $$S_u = 0.495\,(250) = 124 \text{ kpsi}$$
$$= 3.41\,(250) = 853 \text{ MPa} \quad Ans.$$

2-15 For the data given,

$$\sum H_B = 2530 \quad \sum H_B^2 = 640\,226$$

$$\bar{H}_B = \frac{2530}{10} = 253 \quad \hat{\sigma}_{HB} = \sqrt{\frac{640\,226 - (2530)^2/10}{9}} = 3.887$$

Eq. (2-17)

$$\bar{S}_u = 0.495(253) = 125.2 \text{ kpsi} \quad \textit{Ans.}$$

$$\bar{\sigma}_{su} = 0.495(3.887) = 1.92 \text{ kpsi} \quad \textit{Ans.}$$

2-16 From Prob. 2-15, $\bar{H}_B = 253$ and $\hat{\sigma}_{HB} = 3.887$

Eq. (2-18)

$$\bar{S}_u = 0.23(253) - 12.5 = 45.7 \text{ kpsi} \quad \textit{Ans.}$$

$$\hat{\sigma}_{su} = 0.23(3.887) = 0.894 \text{ kpsi} \quad \textit{Ans.}$$

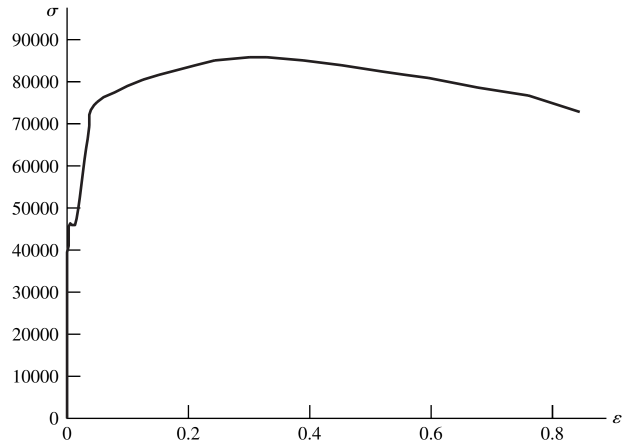
2-17

(a)

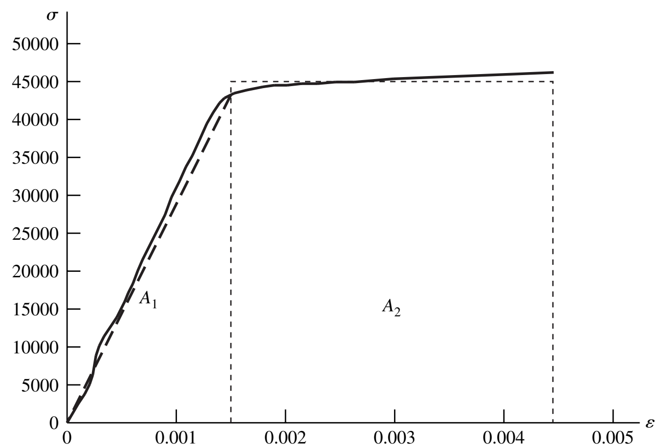
$$u_R \doteq \frac{45.5^2}{2(30)} = 34.5 \text{ in} \cdot \text{lbf/in}^3 \quad \textit{Ans.}$$

(b)

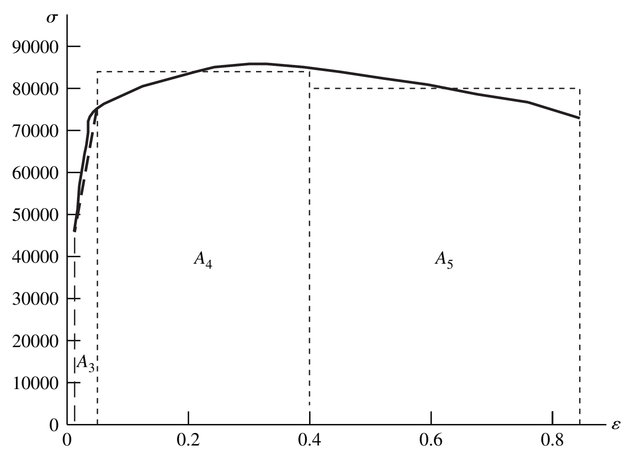
P	ΔL	A	$A_0/A - 1$	ε	$\sigma = P/A_0$
0	0			0	0
1 000	0.0004			0.0002	5 032.39
2 000	0.0006			0.0003	10 064.78
3 000	0.0010			0.0005	15 097.17
4 000	0.0013			0.000 65	20 129.55
7 000	0.0023			0.001 15	35 226.72
8 400	0.0028			0.0014	42 272.06
8 800	0.0036			0.0018	44 285.02
9 200	0.0089			0.004 45	46 297.97
9 100		0.1963	0.012 291	0.012 291	45 794.73
13 200		0.1924	0.032 811	0.032 811	66 427.53
15 200		0.1875	0.059 802	0.059 802	76 492.30
17 000		0.1563	0.271 355	0.271 355	85 550.60
16 400		0.1307	0.520 373	0.520 373	82 531.17
14 800		0.1077	0.845 059	0.845 059	74 479.35



All data points



First 9 data points



Last 6 data points

$$u_T \doteq \sum_{i=1}^{5} A_i = \frac{1}{2}(43\,000)(0.001\,5) + 45\,000(0.004\,45 - 0.001\,5)$$

$$+ \frac{1}{2}(45\,000 + 76\,500)(0.059\,8 - 0.004\,45)$$

$$+ 81\,000(0.4 - 0.059\,8) + 80\,000(0.845 - 0.4)$$

$$\doteq 66.7(10^3)\text{in} \cdot \text{lbf/in}^3 \quad \textit{Ans.}$$

2-18 $m = Al\rho$

For stiffness, $k = AE/l$, or, $A = kl/E$.

Thus, $m = kl^2\rho/E$, and, $M = E/\rho$. Therefore, $\beta = 1$

From Fig. 2-16, ductile materials include Steel, Titanium, Molybdenum, Aluminum, and Composites.

For strength, $S = F/A$, or, $A = F/S$.

Thus, $m = Fl\,\rho/S$, and, $M = S/\rho$.

From Fig. 2-19, lines parallel to S/ρ give for ductile materials, Steel, Nickel, Titanium, and composites.

Common to both stiffness and strength are Steel, Titanium, Aluminum, and Composites. *Ans.*