Solution to HW #1

2-1 From Tables A-20, A-21, A-22, and A-24c,

(a) UNS G10200 HR: $S_{ut} = 380\ (55)$ MPa (kpsi), $S_{yt} = 210\ (30)$ Mpa (kpsi) *Ans.*

(b) SAE 1050 CD: $S_{ut} = 690\ (100)$ MPa (kpsi), $S_{yt} = 580\ (84)$ Mpa (kpsi) *Ans.*

(c) AISI 1141 Q&T at 540°C (1000°F): $S_{ut} = 896\ (130)$ MPa (kpsi), $S_{yt} = 765\ (111)$ Mpa (kpsi) *Ans.*

(d) 2024-T4: $S_{ut} = 446\ (64.8)$ MPa (kpsi), $S_{yt} = 296\ (43.0)$ Mpa (kpsi) *Ans.*

(e) Ti-6Al-4V annealed: $S_{ut} = 900\ (130)$ MPa (kpsi), $S_{yt} = 830\ (120)$ Mpa (kpsi) *Ans.*

2-4

AISI 1018 CD steel: Table A-5

$$\frac{E}{\gamma} = \frac{30.0\left(10^6\right)}{0.282} = 106\left(10^6\right) \text{ in} \quad \textit{Ans.}$$

2011-T6 aluminum: Table A-5

$$\frac{E}{\gamma} = \frac{10.4\left(10^6\right)}{0.098} = 106\left(10^6\right) \text{ in} \quad \textit{Ans.}$$

Ti-6Al-6V titanium: Table A-5

$$\frac{E}{\gamma} = \frac{16.5\left(10^6\right)}{0.160} = 103\left(10^6\right) \text{ in} \quad \textit{Ans.}$$

No. 40 cast iron: Table A-5

$$\frac{E}{\gamma} = \frac{14.5\left(10^6\right)}{0.260} = 55.8\left(10^6\right) \text{ in} \quad \textit{Ans.}$$

2-6 **(a)** $A_0 = \pi(0.503)^2/4$, $\sigma = P_i / A_0$

For data in elastic range, $\epsilon = \Delta l / l_0 = \Delta l / 2$

For data in plastic range, $\epsilon = \dfrac{\Delta l}{l_0} = \dfrac{l - l_0}{l_0} = \dfrac{l}{l_0} - 1 = \dfrac{A_0}{A} - 1$

On the next two pages, the data and plots are presented. Figure (*a*) shows the linear part of the curve from data points 1-7. Figure (*b*) shows data points 1-12. Figure (*c*) shows the complete range. **Note**: The exact value of A_0 is used without rounding off.

(b) From Fig. (*a*) the slope of the line from a linear regression is $E = 30.5$ Mpsi *Ans.*

From Fig. (*b*) the equation for the dotted offset line is found to be

$$\sigma = 30.5(10^6)\epsilon - 61\,000 \qquad (1)$$

The equation for the line between data points 8 and 9 is

$$\sigma = 7.60(10^5)\epsilon + 42\,900 \qquad (2)$$

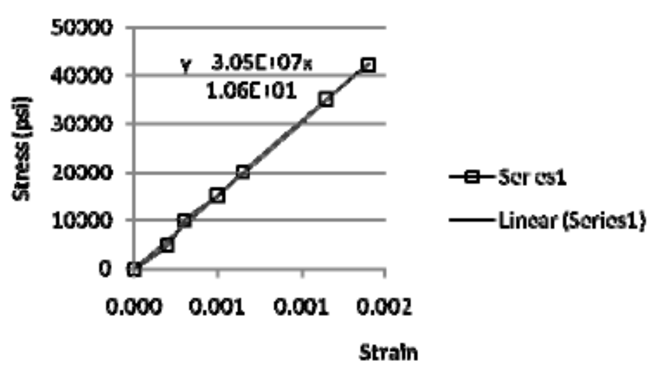
Solving Eqs. (1) and (2) simultaneously yields $\sigma = 45.6$ kpsi which is the 0.2 percent offset yield strength. Thus, $S_y = 45.6$ kpsi *Ans.*

The ultimate strength from Figure (*c*) is $S_u = 85.6$ kpsi *Ans.*

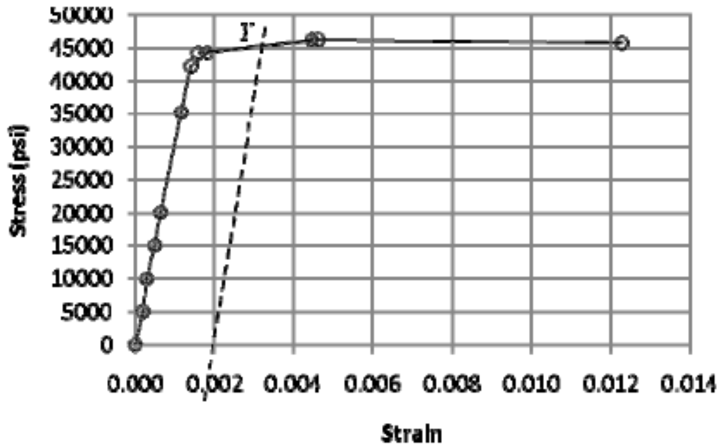
The reduction in area is given by Eq. (2-12) is

$$R = \frac{A_0 - A_f}{A_0}(100) = \frac{0.1987 - 0.1077}{0.1987}(100) = 45.8\ \% \qquad Ans.$$

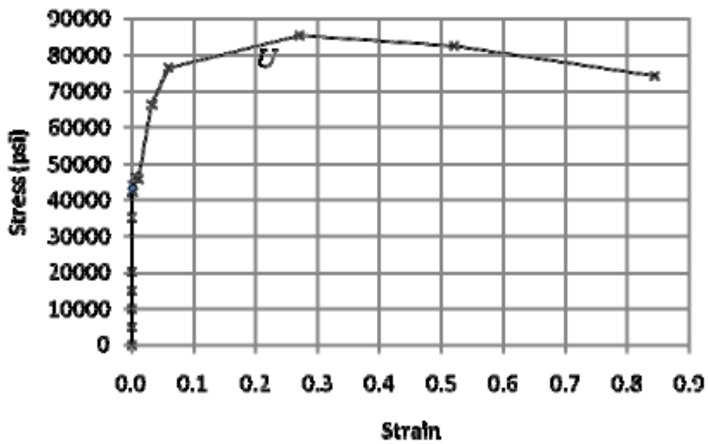
Data Point	P_i	Δl, A_i	ϵ	σ
1	0	0	0	0
2	1000	0.0004	0.00020	5032
3	2000	0.0006	0.00030	10065
4	3000	0.001	0.00050	15097
5	4000	0.0013	0.00065	20130
6	7000	0.0023	0.00115	35227
7	8400	0.0028	0.00140	42272
8	8800	0.0036	0.00180	44285
9	9200	0.0089	0.00445	46298
10	8800	0.1984	0.00158	44285
11	9200	0.1978	0.00461	46298
12	9100	0.1963	0.01229	45795
13	13200	0.1924	0.03281	66428
14	15200	0.1875	0.05980	76492
15	17000	0.1563	0.27136	85551
16	16400	0.1307	0.52037	82531
17	14800	0.1077	0.84506	74479



(*a*) Linear range



(*b*) Offset yield



(*c*) Complete range

(c) The material is ductile since there is a large amount of deformation beyond yield.

(d) The closest material to the values of S_y, S_{ut}, and R is SAE 1045 HR with $S_y = 45$ kpsi, $S_{ut} = 82$ kpsi, and $R = 40$ %. *Ans.*

2-9 $W = 0.20$,

(a) Before cold working: Annealed AISI 1018 steel. Table A-22, $S_y = 32$ kpsi, $S_u = 49.5$ kpsi, $\sigma_0 = 90.0$ kpsi, $m = 0.25$, $\epsilon_f = 1.05$

After cold working: Eq. (2-16), $\epsilon_u = m = 0.25$

Eq. (2-14), $\dfrac{A_0}{A_i} = \dfrac{1}{1-W} = \dfrac{1}{1-0.20} = 1.25$

Eq. (2-17), $\varepsilon_i = \ln\dfrac{A_0}{A_i} = \ln 1.25 = 0.223 < \varepsilon_u$

Eq. (2-18), $S_y{}' = \sigma_0 \varepsilon_i^m = 90(0.223)^{0.25} = 61.8$ kpsi *Ans.* 93% increase *Ans.*

Eq. (2-19), $S_u{}' = \dfrac{S_u}{1-W} = \dfrac{49.5}{1-0.20} = 61.9$ kpsi *Ans.* 25% increase *Ans.*

(b) Before: $\dfrac{S_u}{S_y} = \dfrac{49.5}{32} = 1.55$ After: $\dfrac{S_u{}'}{S_y{}'} = \dfrac{61.9}{61.8} = 1.00$ *Ans.*

Lost most of its ductility

2-14 Eq. (2-21), $0.5H_B = 100 \Rightarrow H_B = 200$ *Ans.*

2-20 Appropriate tables: Young's modulus and Density (Table A-5)1020 HR and CD (Table A-20), 1040 and 4140 (Table A-21), Aluminum (Table A-24), Titanium (Table A-24c)

Appropriate equations:

For diameter, $\sigma = \dfrac{F}{A} = \dfrac{F}{(\pi/4)d^2} = S_y \quad \Rightarrow \quad d = \sqrt{\dfrac{4F}{\pi S_y}}$

Weight/length = ρA, Cost/length = \$/in = (\$/lbf) Weight/length,
Deflection/length = $\delta/L = F/(AE)$

With $F = 100$ kips = $100(10^3)$ lbf,

Material	Young's Modulus	Density	Yield Strength	Cost/lbf	Diameter	Weight/ length	Cost/ length	Deflection/ length
units	Mpsi	lbf/in^3	kpsi	\$/lbf	in	lbf/in	\$/in	in/in
1020 HR	30	0.282	30	\$0.27	2.060	0.9400	\$0.25	1.000E-03
1020 CD	30	0.282	57	\$0.30	1.495	0.4947	\$0.15	1.900E-03
1040	30	0.282	80	\$0.35	1.262	0.3525	\$0.12	2.667E-03
4140	30	0.282	165	\$0.80	0.878	0.1709	\$0.14	5.500E-03
Al	10.4	0.098	50	\$1.10	1.596	0.1960	\$0.22	4.808E-03
Ti	16.5	0.16	120	\$7.00	1.030	0.1333	\$0.93	7.273E-03

The selected materials with minimum values are shaded in the table above. *Ans.*

2-20 Appropriate tables: Young's modulus and Density (Table A-5)1020 HR and CD (Table A-20), 1040 and 4140 (Table A-21), Aluminum (Table A-24), Titanium (Table A-24c)

Appropriate equations:

For diameter, $\sigma = \dfrac{F}{A} = \dfrac{F}{(\pi/4)d^2} = S_y \quad \Rightarrow \quad d = \sqrt{\dfrac{4F}{\pi S_y}}$

Weight/length = ρA, Cost/length = \$/in = (\$/lbf) Weight/length,
Deflection/length = $\delta/L = F/(AE)$

With F = 100 kips = 100(10^3) lbf,

Material	Young's Modulus	Density	Yield Strength	Cost/lbf	Diameter	Weight/ length	Cost/ length	Deflection/ length
units	Mpsi	lbf/in^3	kpsi	\$/lbf	in	lbf/in	\$/in	in/in
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The selected materials with minimum values are shaded in the table above. *Ans.*

2-28 For strength,

$$\sigma = Fl/Z = S \qquad (1)$$

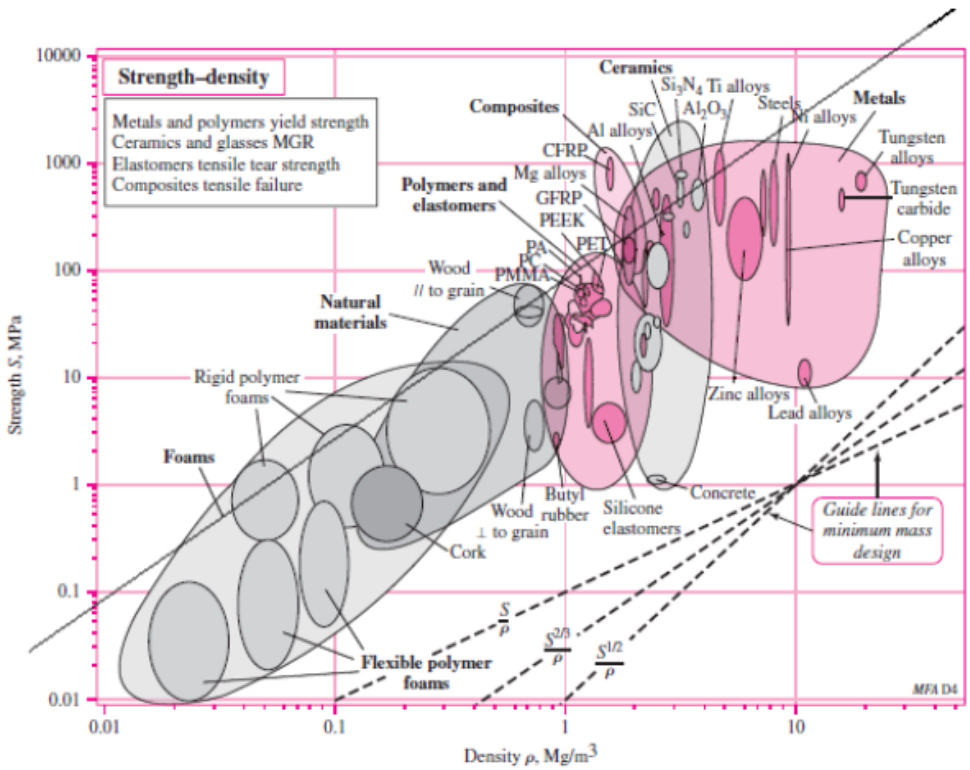
where Fl is the bending moment and Z is the section modulus [see Eq. (3-26*b*), p. 90]. The section modulus is strictly a function of the dimensions of the cross section and has the units in^3 (ips) or m^3 (SI). Thus, for a given cross section, $Z = C(A)^{3/2}$, where C is a number. For example, for a circular cross section, $C = \left(4\sqrt{\pi}\right)^{-1}$. Then, for strength, Eq. (1) is

$$\frac{Fl}{CA^{3/2}} = S \quad \Rightarrow \quad A = \left(\frac{Fl}{CS}\right)^{2/3} \qquad (2)$$

For mass, $$m = Al\rho = \left(\frac{Fl}{CS}\right)^{2/3} l\rho = \left(\frac{F}{C}\right)^{2/3} l^{5/3}\left(\frac{\rho}{S^{2/3}}\right)$$

Thus, $f_3(M) = \rho/S^{2/3}$, and maximize $S^{2/3}/\rho$ $(\beta = 2/3)$

In Fig. (2-19), draw lines parallel to $S^{2/3}/\rho$



From the list of materials given, a higher strength **aluminum alloy** has the greatest potential, followed closely by high carbon heat-treated steel. Tungsten carbide is clearly not a good choice compared to the other candidate materials. *Ans.*