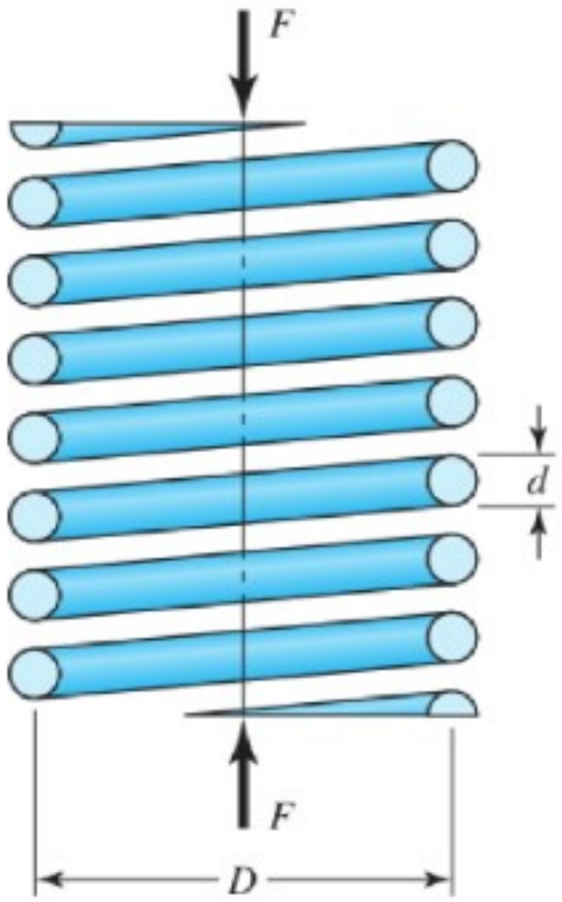
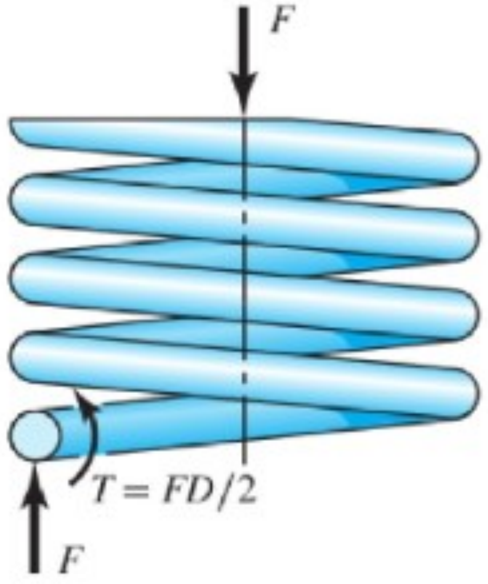


(a)



(b)

Helical Springs

$$T = \frac{FD}{2}$$

$$\tau_{max} = \frac{Tr}{J} + \frac{F}{A}$$

$$\tau_{max} = \tau$$

$$r = d/2$$

$$J = \pi d^4/32$$

$$A = \pi d^2/4$$

$$\tau = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2}$$

Spring index

$$C = D/d$$

$$\tau = K_s \frac{8FD}{\pi d^3}$$

$$K_s = \frac{2C+1}{2C}$$

Straight wire

$$K_W = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$ Whol Factor

1% difference

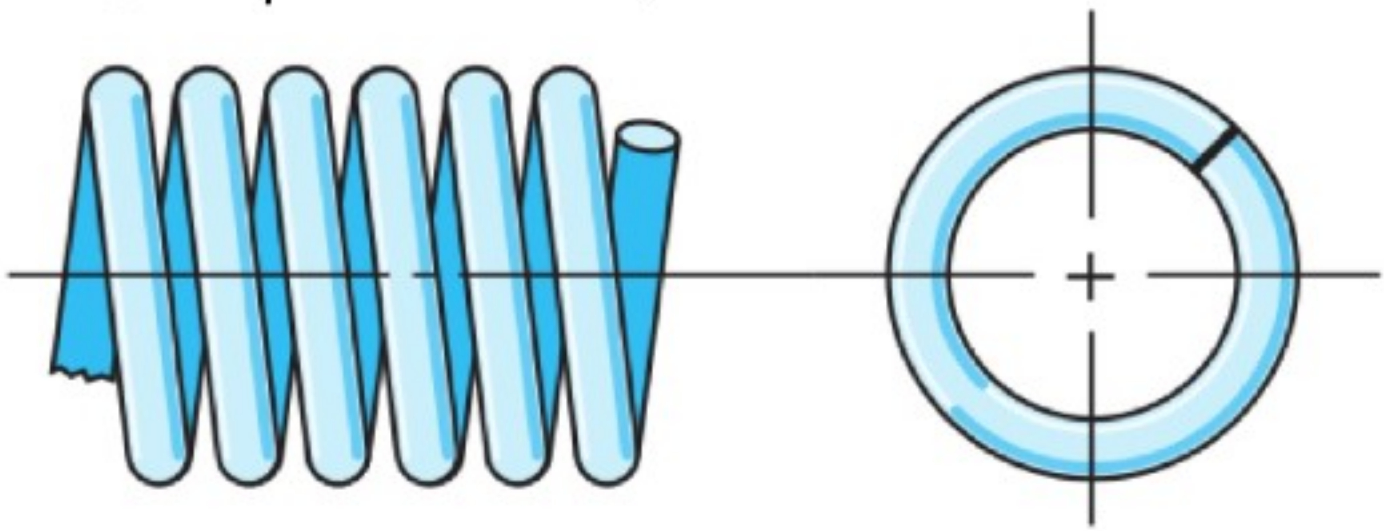
$$K_B = \frac{4C+2}{4C-3}$$ Bergstrasser factor

$$\tau = K_B \frac{8FD}{\pi d^3}$$

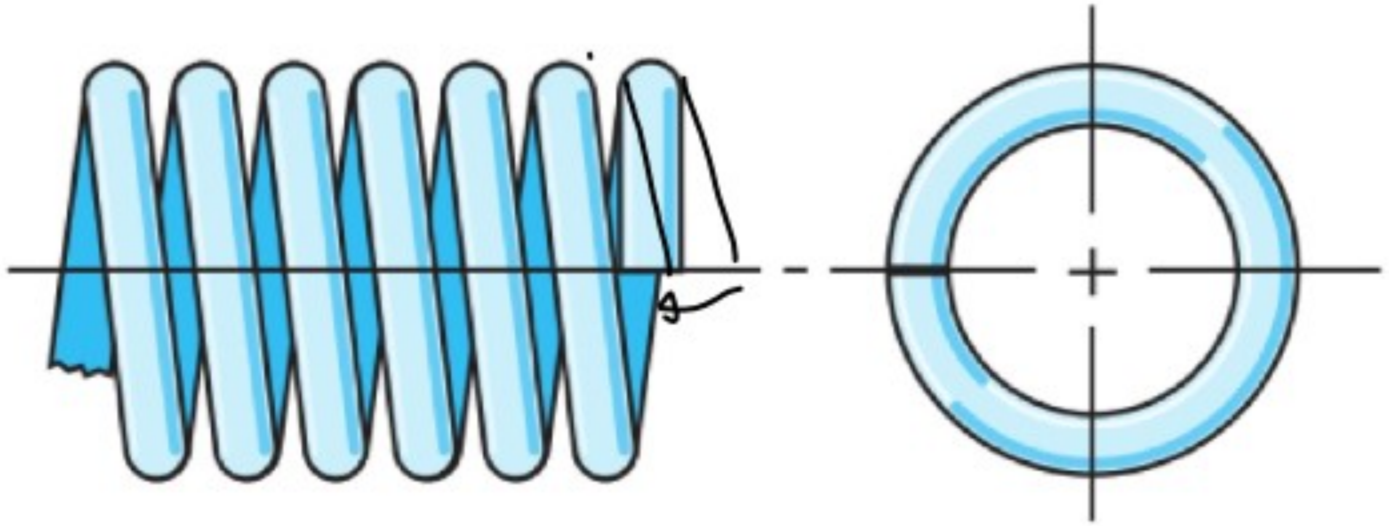
Spring Constant $F = kx$

$$k = \frac{d^4 G}{8D^3 N}$$

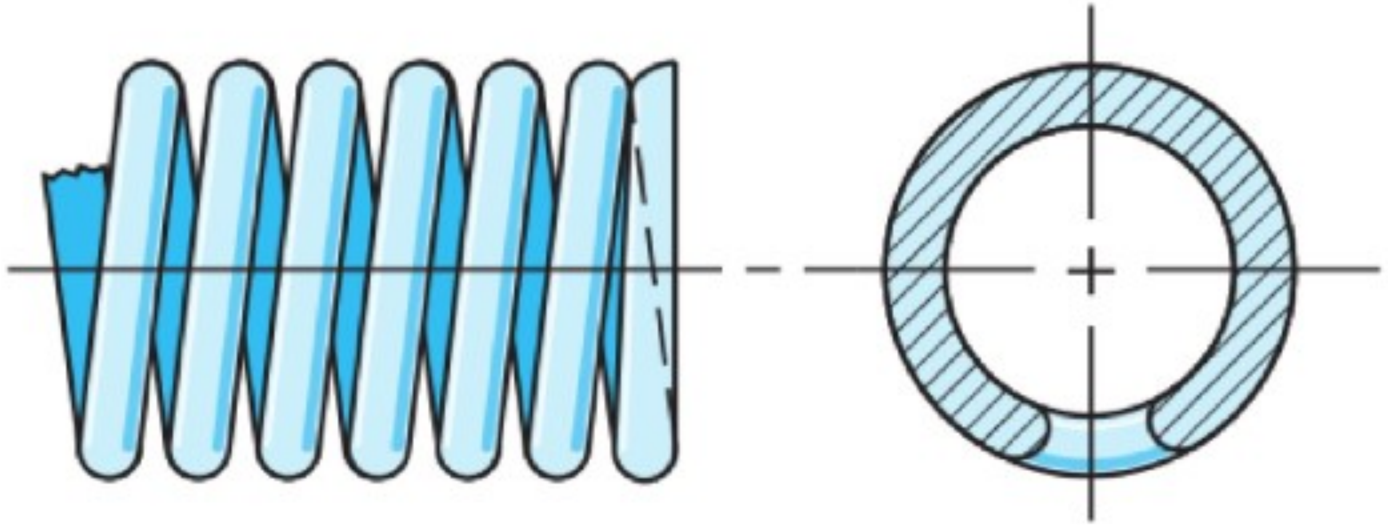
Compression Springs



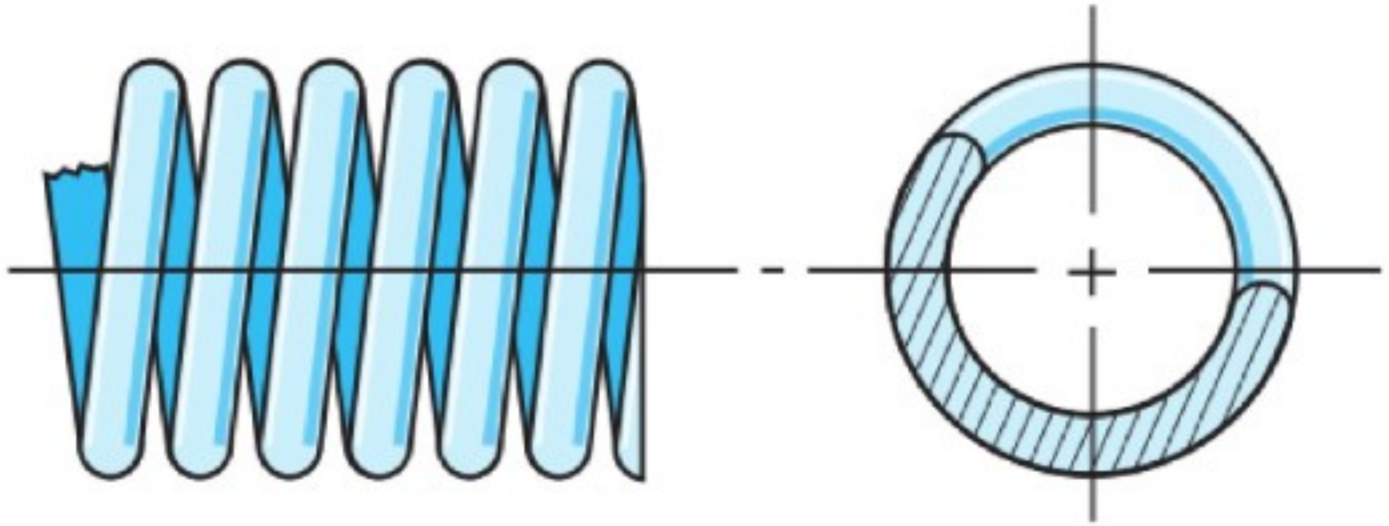
(*a*) Plain end, right hand



(*b*) Squared or closed end, right hand



(*c*) Squared and ground end, left hand



(*d*) Plain end, ground, left hand

Table 10–1

		Type of Spring Ends		
Term	Plain	Plain and Ground	Squared or Closed	Squared and Ground
End coils, N_e	0	1	2	2
Total coils, N_t	N_a	$N_a + 1$	$N_a + 2$	$N_a + 2$
Free length, L_0	$pN_a + d$	$p(N_a + 1)$	$pN_a + 3d$	$pN_a + 2d$
Solid length, L_s	$d(N_t + 1)$	dN_t	$d(N_t + 1)$	dN_t
Pitch, p	$(L_0 - d)/N_a$	$L_0/(N_a + 1)$	$(L_0 - 3d)/N_a$	$(L_0 - 2d)/N_a$

N_a active coils

Buckling

$$y_{cr} = L_0 C_1' \left(1 - \sqrt{1 - C_2' / \lambda_{eff}^2}\right)$$

Table 10-3

Name of Material	Similar Specifications	Description
Music wire, 0.80–0.95*C*	UNS G10850 AISI 1085 ASTM A228-51	This is the best, toughest, and most widely used of all spring materials for small springs. It has the highest tensile strength and can withstand higher stresses under repeated loading than any other spring material. Available in diameters 0.12 to 3 mm (0.005 to 0.125 in). Do not use above 120°C (250°F) or at subzero temperatures.
Oil-tempered wire, 0.60–0.70*C*	UNS G10650 AISI 1065 ASTM 229-41	This general-purpose spring steel is used for many types of coil springs where the cost of music wire is prohibitive and in sizes larger than available in music wire. Not for shock or impact loading. Available in diameters 3 to 12 mm (0.125 to 0.5000 in), but larger and smaller sizes may be obtained. Not for use above 180°C (350°F) or at subzero temperatures.
Hard-drawn wire, 0.60–0.70*C*	UNS G10660 AISI 1066 ASTM A227-47	This is the cheapest general-purpose spring steel and should be used only where life, accuracy, and deflection are not too important. Available in diameters 0.8 to 12 mm (0.031 to 0.500 in). Not for use above 120°C (250°F) or at subzero temperatures.
Chrome-vanadium	UNS G61500 AISI 6150 ASTM 231-41	This is the most popular alloy spring steel for conditions involving higher stresses than can be used with the high-carbon steels and for use where fatigue resistance and long endurance are needed. Also good for shock and impact loads. Widely used for aircraft-engine valve springs and for temperatures to 220°C (425°F). Available in annealed or pretempered sizes 0.8 to 12 mm (0.031 to 0.500 in) in diameter.
Chrome-silicon	UNS G92540 AISI 9254	This alloy is an excellent material for highly stressed springs that require long life and are subjected to shock loading. Rockwell hardnesses of C50 to C53 are quite common, and the material may be used up to 250°C (475°F). Available from 0.8 to 12 mm (0.031 to 0.500 in) in diameter.

Table 10-4

Material	ASTM No.	Exponent m	Diameter, in	A, kpsi · in^m	Diameter, mm	A, MPa · mm^m	Relative Cost of Wire
Music wire*	A228	0.145	0.004–0.256	201	0.10–6.5	2211	2.6
OQ&T wire†	A229	0.187	0.020–0.500	147	0.5–12.7	1855	1.3
Hard-drawn wire‡	A227	0.190	0.028–0.500	140	0.7–12.7	1783	1.0
Chrome-vanadium wire§	A232	0.168	0.032–0.437	169	0.8–11.1	2005	3.1
Chrome-silicon wire‖	A401	0.108	0.063–0.375	202	1.6–9.5	1974	4.0
302 Stainless wire#	A313	0.146	0.013–0.10	169	0.3–2.5	1867	7.6–11
		0.263	0.10–0.20	128	2.5–5	2065	
		0.478	0.20–0.40	90	5–10	2911	
Phosphor-bronze wire**	B159	0	0.004–0.022	145	0.1–0.6	1000	8.0
		0.028	0.022–0.075	121	0.6–2	913	
		0.064	0.075–0.30	110	2–7.5	932	

$$S_{ut} = \frac{A}{d^m}$$

$$0.35\,S_{ut} \le S_{sy} \le 0.52\,S_{ut}$$

Design

$$4 \le C \le 12$$

$$3 \le N_a \le 15$$

Fractional overrun to closure

$$\xi \ge 0.15 \qquad F_s = (1+\xi)F_{max}$$

$$\frac{S_{sy}}{n_s} = K_B \frac{8F_sD}{\pi d^3} = \frac{4C+2}{4C-3}\left(\frac{8(1+\xi)F_{max}C}{\pi d^2}\right)$$

$$\alpha = \frac{S_{sy}}{n_s} \qquad \beta = \frac{8(1+\xi)F_{max}}{\pi d^2}$$

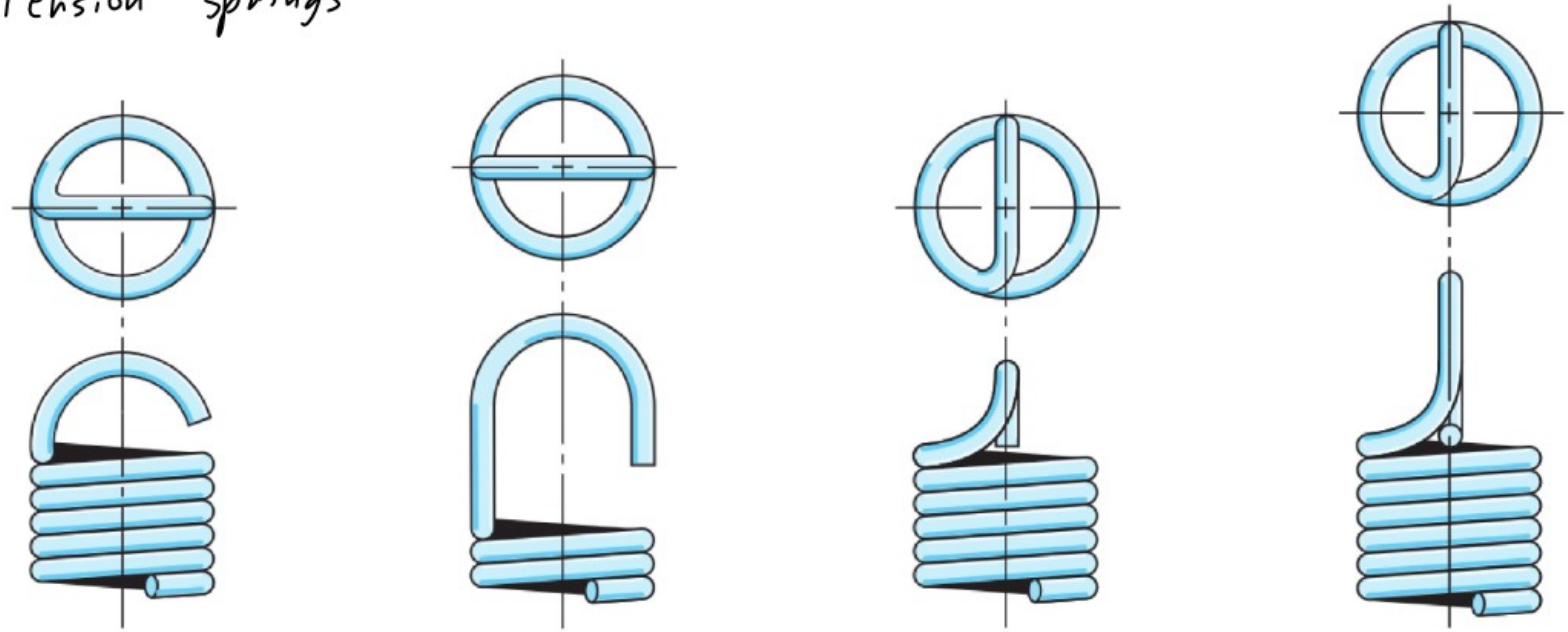
$$C = \frac{2\alpha-\beta}{4\beta} + \sqrt{\left(\frac{2\alpha-\beta}{4\beta}\right)^2 - \frac{3\alpha}{4\beta}}$$

Fatigue

Infinite life

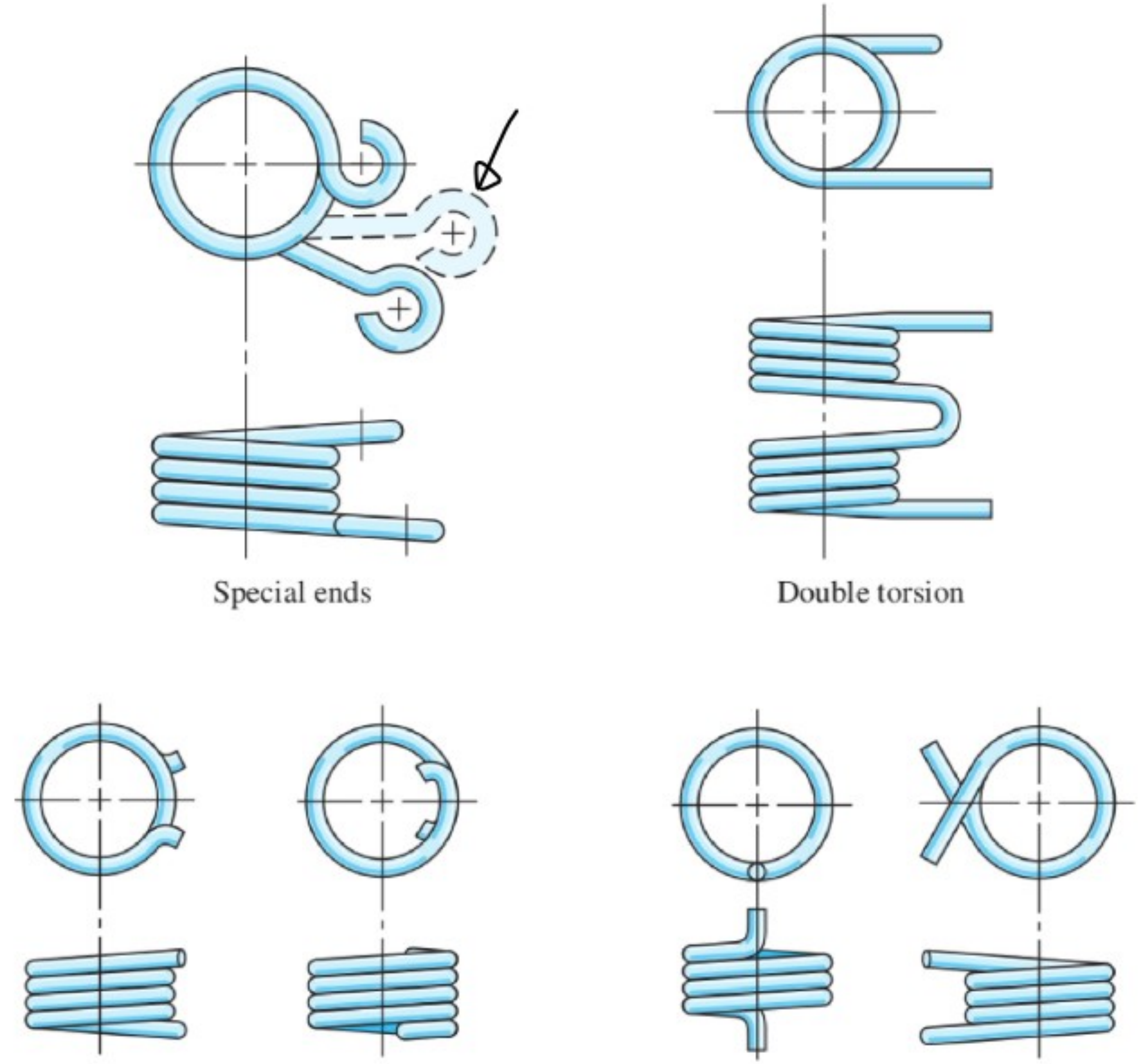
$S_{se} = 37.5$ Kpsi for spring steel with $d < 3/8$ in

Tension springs



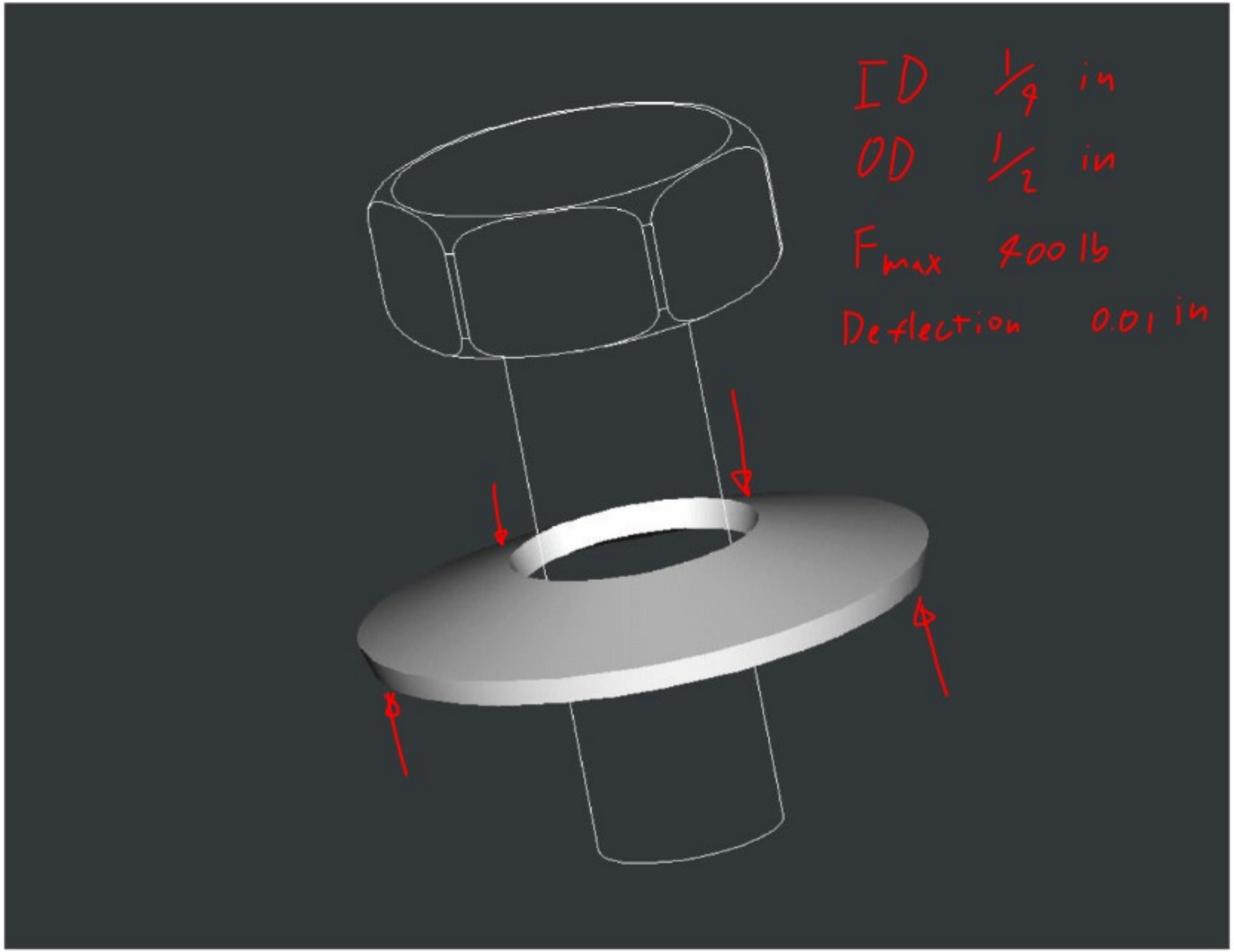
(*a*) Machine half loop–open (*b*) Raised hook (*c*) Short twisted loop (*d*) Full twisted loop

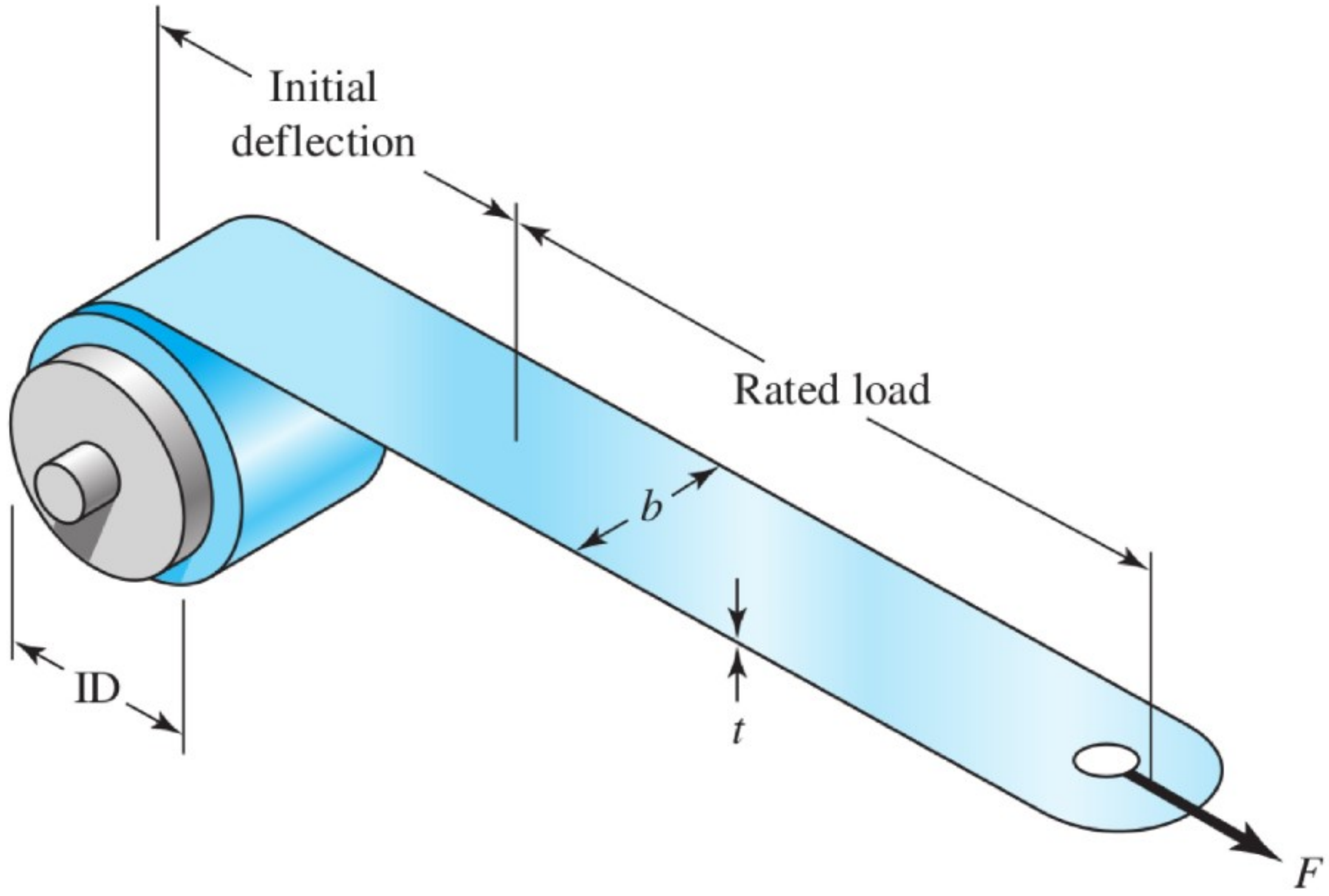
Torsion Springs

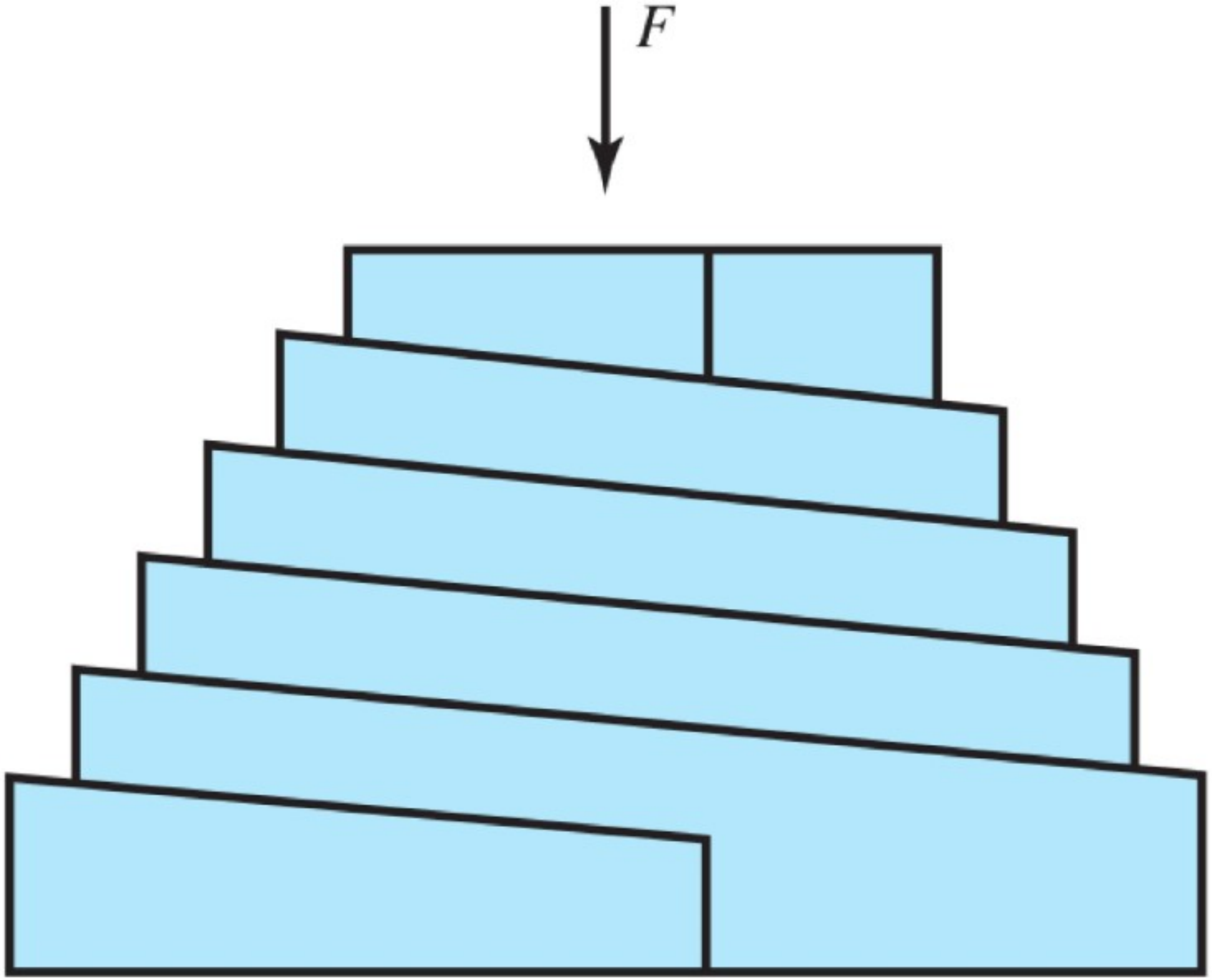


Special ends
Double torsion
Short hook ends
Hinge ends
Straight offset
Straight torsion

Belleville Washer




Initial
deflection
Rated load
b
t
ID
F


F

A helical compression spring is wound using 2.5-mm-diameter music wire. The spring has an outside diameter of 31 mm with plain ground ends, and 14 total coils.

(*a*) Estimate the spring rate.

(*b*) What force is needed to compress this spring to closure?

(*c*) What should the free length be to ensure that when the spring is compressed solid the torsional stress does not exceed the yield strength?

(*d*) Is there a possibility that the spring might buckle in service?