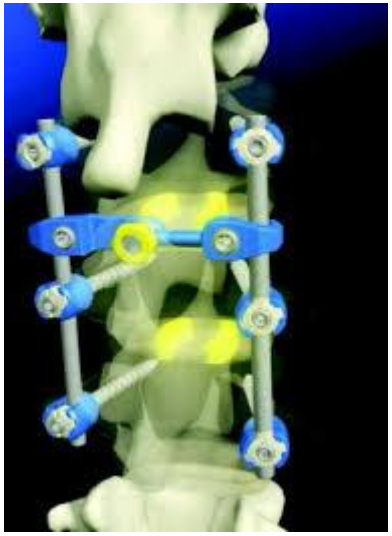
Joint Fasteners

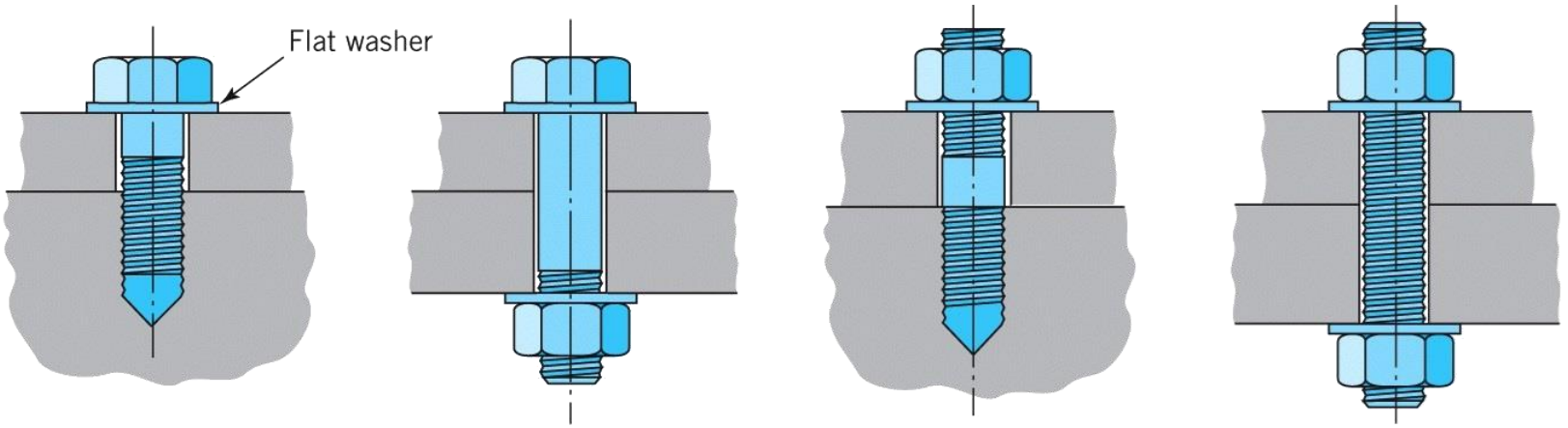
- **Types of Fasteners**
- **Joints-Fastener Stiffness**
- **Joints-Member Stiffness**







Fasteners Classification by Intended Use

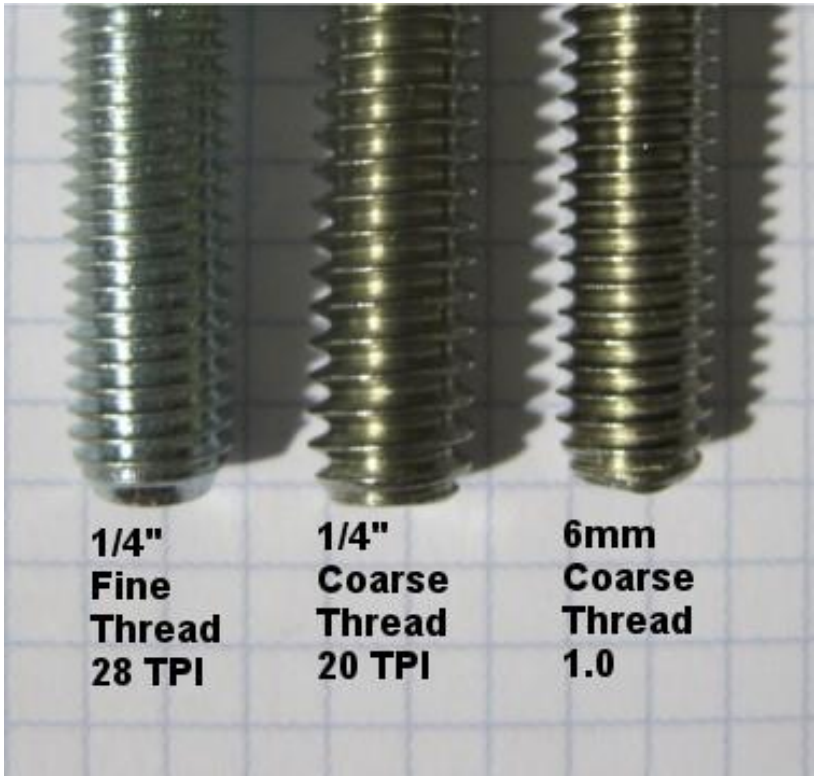


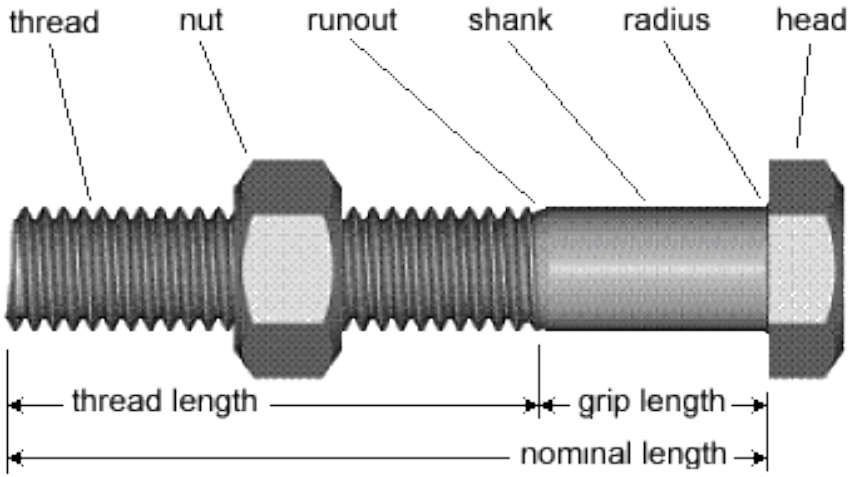
Sometimes includes a captive washer, often a lock washer. In this case it is Referred to as a "sems"

Usually used when a vary long threaded member is needed

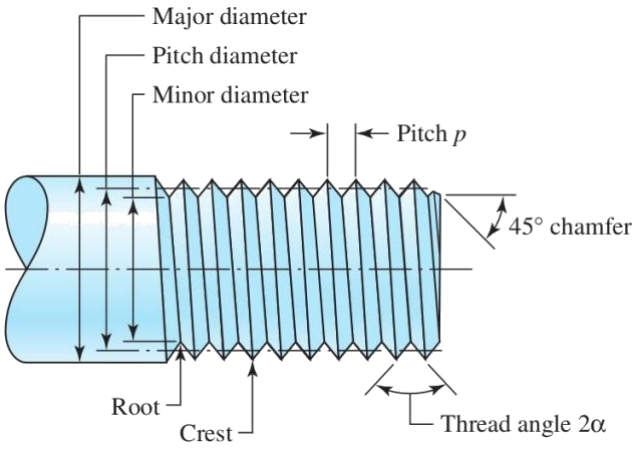
Not shown are Carriage Bolts with square corners that dig into soft materials preventing turning

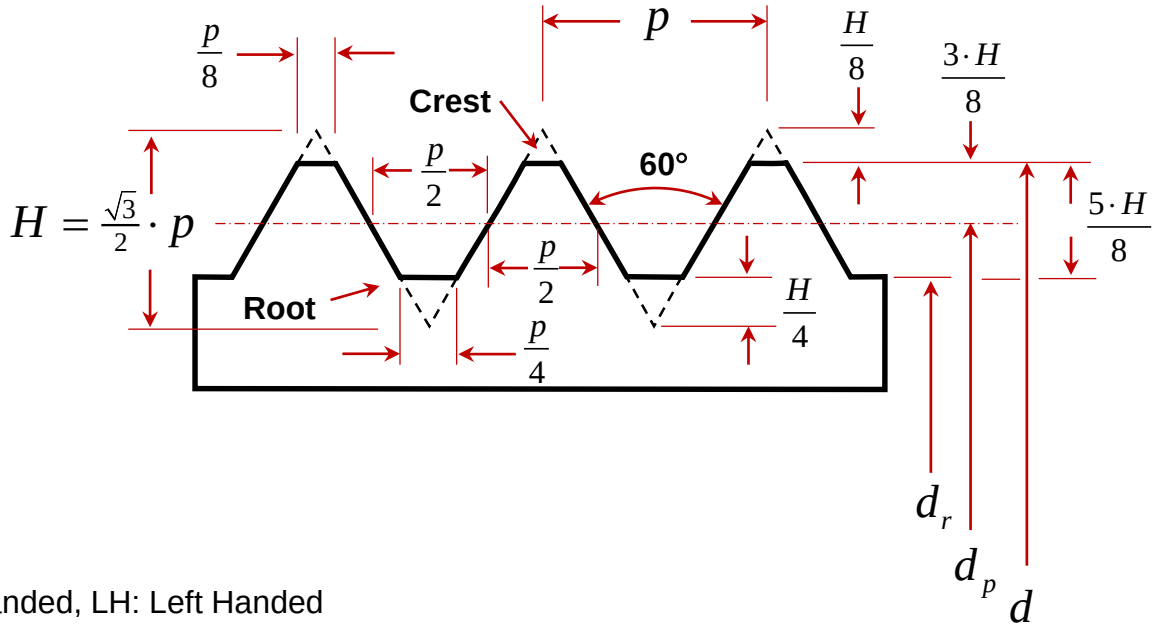
Basic Terminology





Unified Thread Standard





$\frac{1}{2}-12\,UNC-3A\;\;LH$

RH: Right Handed, LH: Left Handed

A: External Threads, B: Internal Threads

TOLERANCE SPECIFICATION (Class of Fit):
1: Hardware Quality
2: General Machine Design
3: Highest Class of Fit

CLASSIFICATION:
UNC: Ordinary Applications
Repeated Insertions and Removals
Insertion into a Softer Material
UNF: Applications Subject to Vibration
UNEF: Limited Wall Thickness

Threads per Inch, 1/p

d, Major Diameter (<1/4" are numbered by gauge, d~#·13+60 [in thousandths of an inch]

Unified Screw Thread Critical Parameters

		Coarse Series—UNC			Fine Series—UNF		
Size Designation	Nominal Major Diameter in	Threads per Inch N	Tensile-Stress Area A_t, in^2	Minor-Diameter Area A_r, in^2	Threads per Inch N	Tensile-Stress Area A_t, in^2	Minor-Diameter Area A_r, in^2
0	0.0600				80	0.001 80	0.001 51
1	0.0730	64	0.002 63	0.002 18	72	0.002 78	0.002 37
2	0.0860	56	0.003 70	0.003 10	64	0.003 94	0.003 39
3	0.0990	48	0.004 87	0.004 06	56	0.005 23	0.004 51
4	0.1120	40	0.006 04	0.004 96	48	0.006 61	0.005 66
5	0.1250	40	0.007 96	0.006 72	44	0.008 80	0.007 16
6	0.1380	32	0.009 09	0.007 45	40	0.010 15	0.008 74
8	0.1640	32	0.014 0	0.011 96	36	0.014 74	0.012 85
10	0.1900	24	0.017 5	0.014 50	32	0.020 0	0.017 5
12	0.2160	24	0.024 2	0.020 6	28	0.025 8	0.022 6
$\frac{1}{4}$	0.2500	20	0.031 8	0.026 9	28	0.036 4	0.032 6
$\frac{5}{16}$	0.3125	18	0.052 4	0.045 4	24	0.058 0	0.052 4
$\frac{3}{8}$	0.3750	16	0.077 5	0.067 8	24	0.087 8	0.080 9
$\frac{7}{16}$	0.4375	14	0.106 3	0.093 3	20	0.118 7	0.109 0
$\frac{1}{2}$	0.5000	13	0.141 9	0.125 7	20	0.159 9	0.148 6
$\frac{9}{16}$	0.5625	12	0.182	0.162	18	0.203	0.189
$\frac{5}{8}$	0.6250	11	0.226	0.202	18	0.256	0.240
$\frac{3}{4}$	0.7500	10	0.334	0.302	16	0.373	0.351
$\frac{7}{8}$	0.8750	9	0.462	0.419	14	0.509	0.480
1	1.0000	8	0.606	0.551	12	0.663	0.625
$1\frac{1}{4}$	1.2500	7	0.969	0.890	12	1.073	1.024
$1\frac{1}{2}$	1.5000	6	1.405	1.294	12	1.581	1.521

$d \equiv$ Major diameter, largest diameter

$d_r \equiv$ Minor or root diameter

$= d - 1.299038 / N$

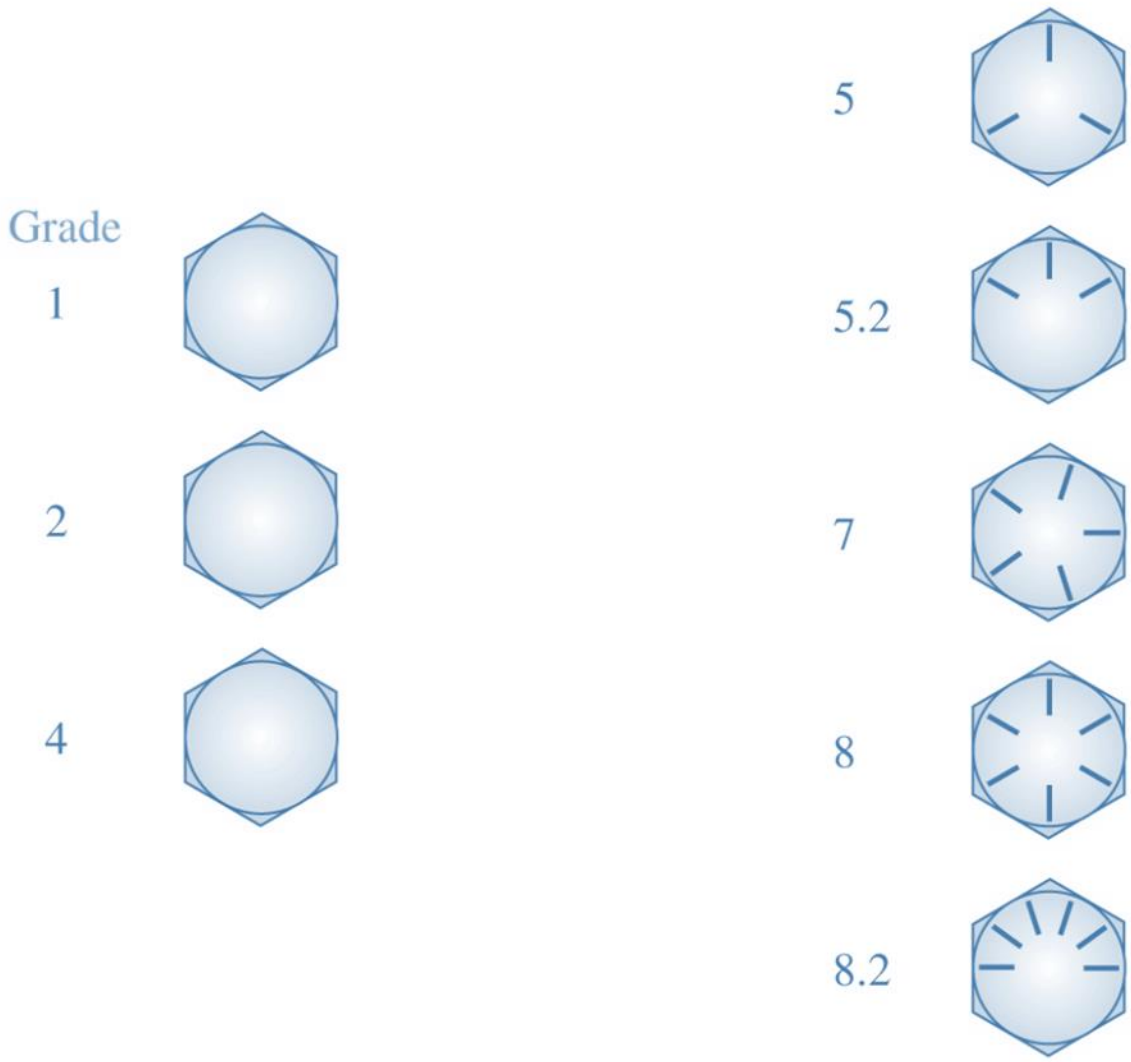
$d_p \equiv$ Pitch diameter

$= d - 0.649519 / N$

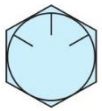
Mean of d_p and d_r used to compute Tensile Stress Area

$$A_t = \frac{\pi}{4} \cdot \left(\frac{d_p + d_r}{2} \right)^2$$

Head Marks for SAE Bolts (Imperial)



SAE Specifications for Steel Bolts

SAE Grade No.	Size Range Inclusive, in	Minimum Proof Strength,* kpsi	Minimum Tensile Strength,* kpsi	Minimum Yield Strength,* kpsi	Material	Head Marking
1	$\frac{1}{4}$–$1\frac{1}{2}$	33	60	36	Low or medium carbon	
2	$\frac{1}{4}$–$\frac{3}{4}$	55	74	57	Low or medium carbon	
	$\frac{7}{8}$–$1\frac{1}{2}$	33	60	36		
4	$\frac{1}{4}$–$1\frac{1}{2}$	65	115	100	Medium carbon, cold-drawn	
5	$\frac{1}{4}$–1	85	120	92	Medium carbon, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
5.2	$\frac{1}{4}$–1	85	120	92	Low-carbon martensite, Q&T	
7	$\frac{1}{4}$–$1\frac{1}{2}$	105	133	115	Medium-carbon alloy, Q&T	
8	$\frac{1}{4}$–$1\frac{1}{2}$	120	150	130	Medium-carbon alloy, Q&T	
8.2	$\frac{1}{4}$–1	120	150	130	Low-carbon martensite, Q&T	

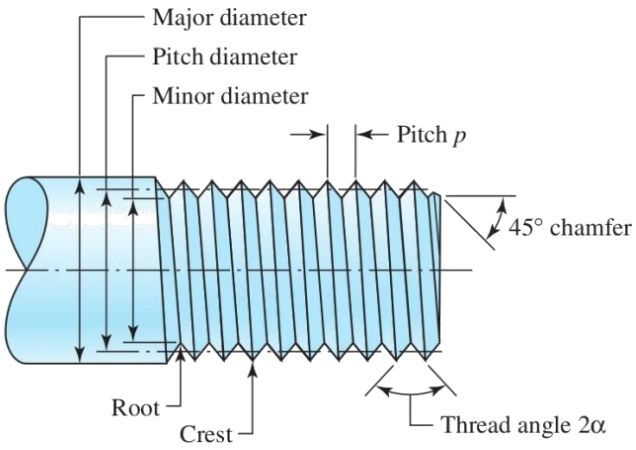
*Minimum strengths are strengths exceeded by 99 percent of fasteners.

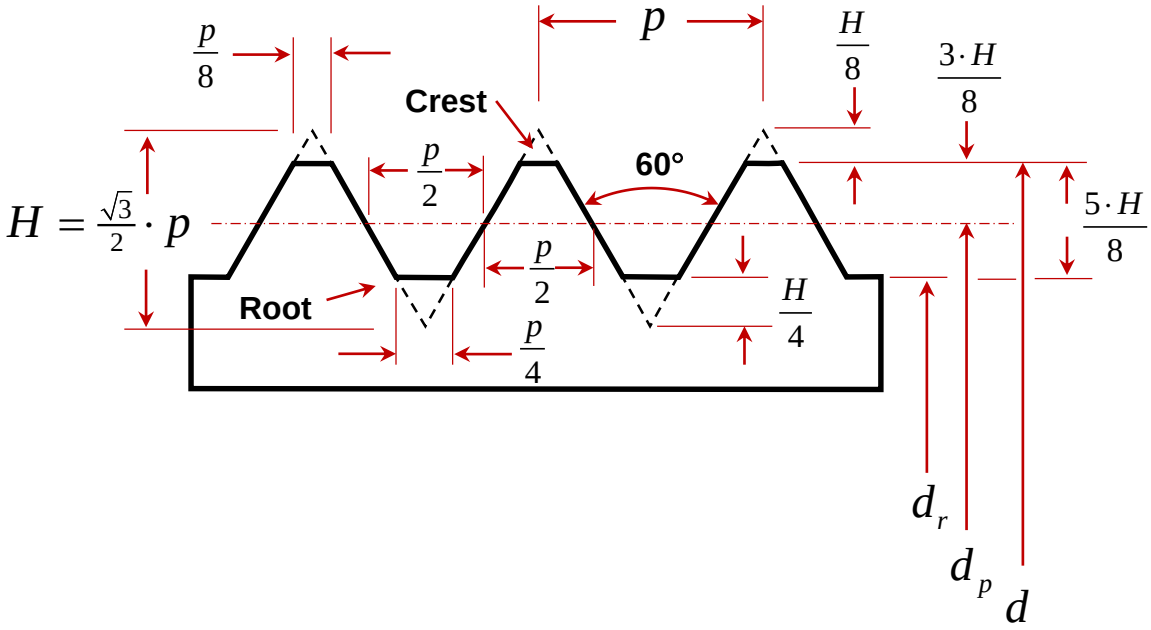
ASTM Specifications for Steel Bolts

ASTM Designation No.	Size Range, Inclusive, in	Minimum Proof Strength,* kpsi	Minimum Tensile Strength,* kpsi	Minimum Yield Strength,* kpsi	Material	Head Marking
A307	$\frac{1}{4}$–$1\frac{1}{2}$	33	60	36	Low carbon	
A325, type 1	$\frac{1}{2}$–1	85	120	92	Medium carbon, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
A325, type 2	$\frac{1}{2}$–1	85	120	92	Low-carbon, martensite, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
A325, type 3	$\frac{1}{2}$–1	85	120	92	Weathering steel, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
A354, grade BC	$\frac{1}{4}$–$2\frac{1}{2}$	105	125	109	Alloy steel, Q&T	
	$2\frac{3}{4}$–4	95	115	99		
A354, grade BD	$\frac{1}{4}$–4	120	150	130	Alloy steel, Q&T	
A449	$\frac{1}{4}$–1	85	120	92	Medium-carbon, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
	$1\frac{3}{4}$–3	55	90	58		
A490, type 1	$\frac{1}{2}$–$1\frac{1}{2}$	120	150	130	Alloy steel, Q&T	
A490, type 3	$\frac{1}{2}$–$1\frac{1}{2}$	120	150	130	Weathering steel, Q&T	

*Minimum strengths are strengths exceeded by 99 percent of fasteners.

Metric Screw Threads





$M\,12\;x\,1.75,\,6g\;x\,85$

- Length
- Fit Classification
- Pitch p
- Major Diameter d in mm
- M: Metric, MJ: Rounded fillet at root of external thread, and a larger minor diameter of both the internal and external threads. These are useful in fatigue applications.

Metric Thread Critical Parameters

Nominal Major Diameter d mm	Coarse-Pitch Series Pitch p mm	Tensile-Stress Area A_t mm^2	Minor-Diameter Area A_r mm^2	Fine-Pitch Series Pitch p mm	Tensile-Stress Area A_t mm^2	Minor-Diameter Area A_r mm^2
1.6	0.35	1.27	1.07			
2	0.40	2.07	1.79			
2.5	0.45	3.39	2.98			
3	0.5	5.03	4.47			
3.5	0.6	6.78	6.00			
4	0.7	8.78	7.75			
5	0.8	14.2	12.7			
6	1	20.1	17.9			
8	1.25	36.6	32.8	1	39.2	36.0
10	1.5	58.0	52.3	1.25	61.2	56.3
12	1.75	84.3	76.3	1.25	92.1	86.0
14	2	115	104	1.5	125	116
16	2	157	144	1.5	167	157
20	2.5	245	225	1.5	272	259
24	3	353	324	2	384	365
30	3.5	561	519	2	621	596
36	4	817	759	2	915	884
42	4.5	1120	1050	2	1260	1230
48	5	1470	1380	2	1670	1630
56	5.5	2030	1910	2	2300	2250
64	6	2680	2520	2	3030	2980
72	6	3460	3280	2	3860	3800
80	6	4340	4140	1.5	4850	4800
90	6	5590	5360	2	6100	6020
100	6	6990	6740	2	7560	7470
110				2	9180	9080

$d \equiv$ Major diameter, largest diameter

$d_r \equiv$ Minor or root diameter

$= d - 1.226869 \cdot p$

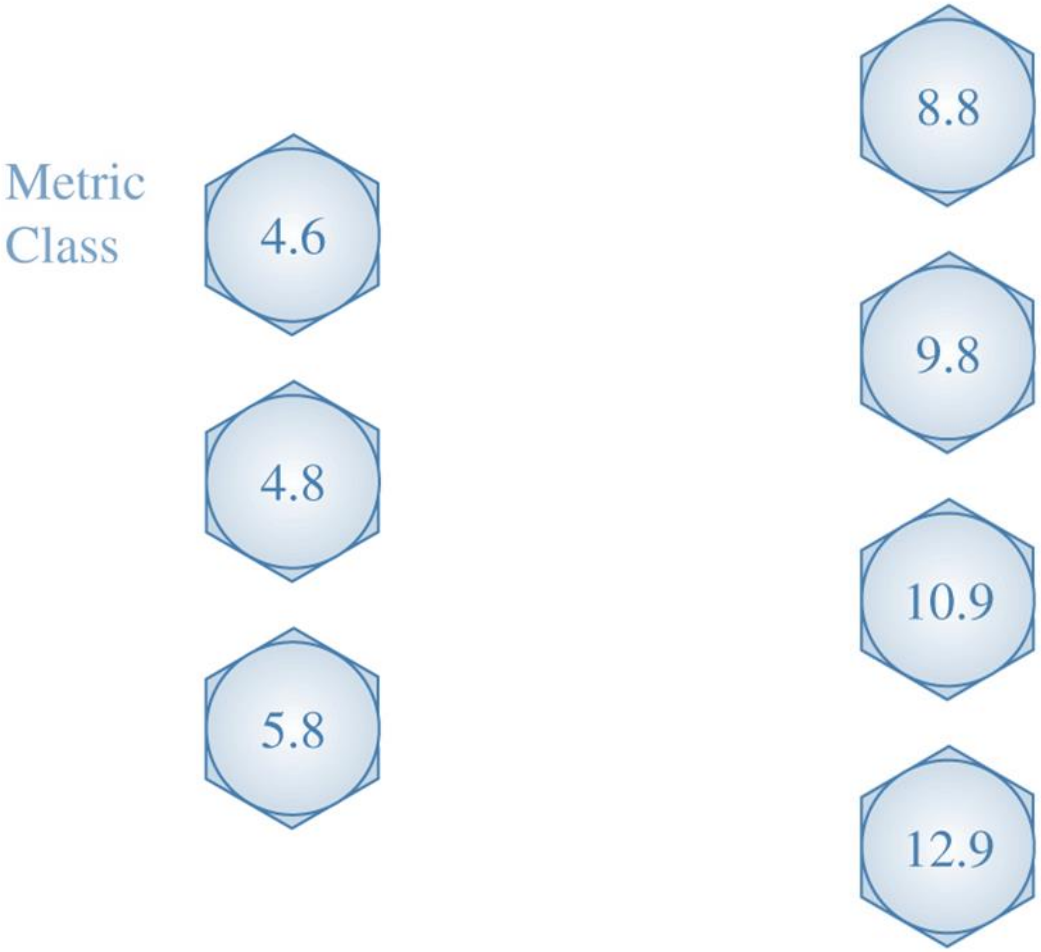
$d_p \equiv$ Pitch diameter

$= d - 0.649519 \cdot p$

Mean of d_p and d_r used to compute Tensile Stress Area

$$A_t = \frac{\pi}{4} \cdot \left(\frac{d_p + d_r}{2} \right)^2$$

Head Marks – Metric Bolts

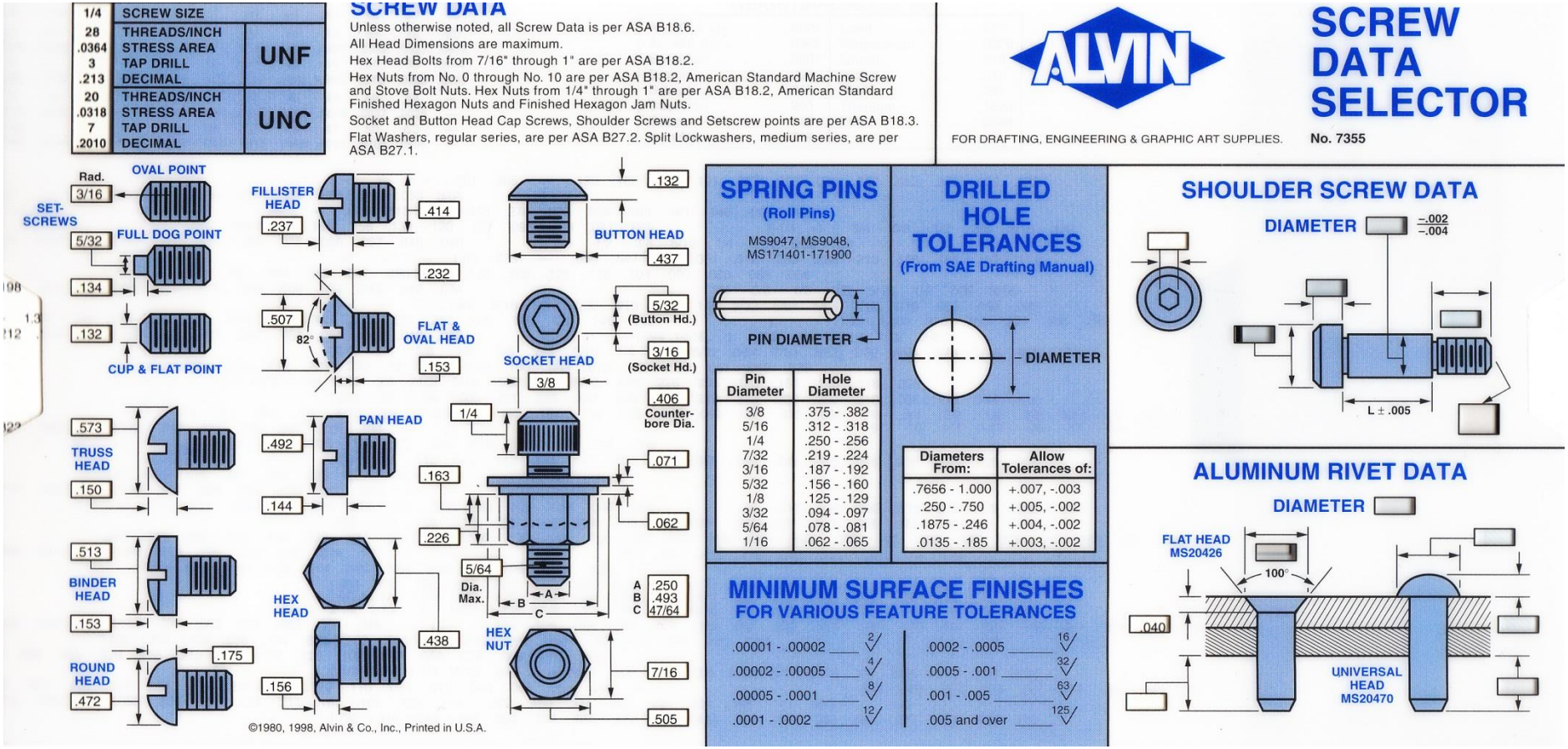


Metric Properties for Steel Bolts,Screws, and Studs

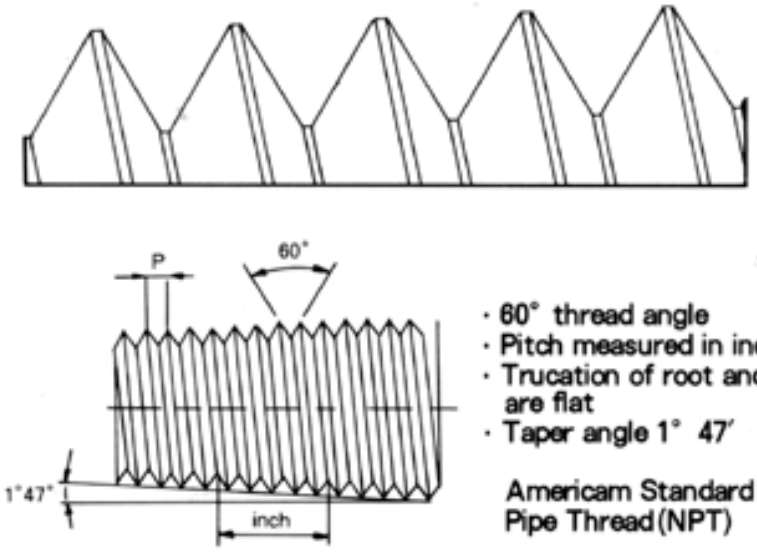
Property Class	Size Range, Inclusive	Minimum Proof Strength,* MPa	Minimum Tensile Strength,* MPa	Minimum Yield Strength,* MPa	Material	Head Marking
4.6	M5–M36	225	400	240	Low or medium carbon	
4.8	M1.6–M16	310	420	340	Low or medium carbon	
5.8	M5–M24	380	520	420	Low or medium carbon	
8.8	M16–M36	600	830	660	Medium carbon, Q&T	
9.8	M1.6–M16	650	900	720	Medium carbon, Q&T	
10.9	M5–M36	830	1040	940	Low-carbon martensite, Q&T	
12.9	M1.6–M36	970	1220	1100	Alloy, Q&T	

*Minimum strengths are strengths exceeded by 99 percent of fasteners.

Tools for Design



Taper Pipe Series (NPT)



- 60° thread angle
- Pitch measured in inches
- Trucation of root and crest are flat
- Taper angle 1° 47′

Americam Standard Pipe Thread (NPT)

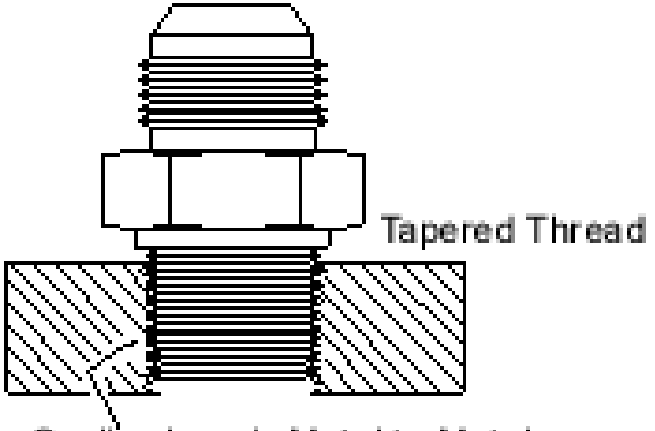
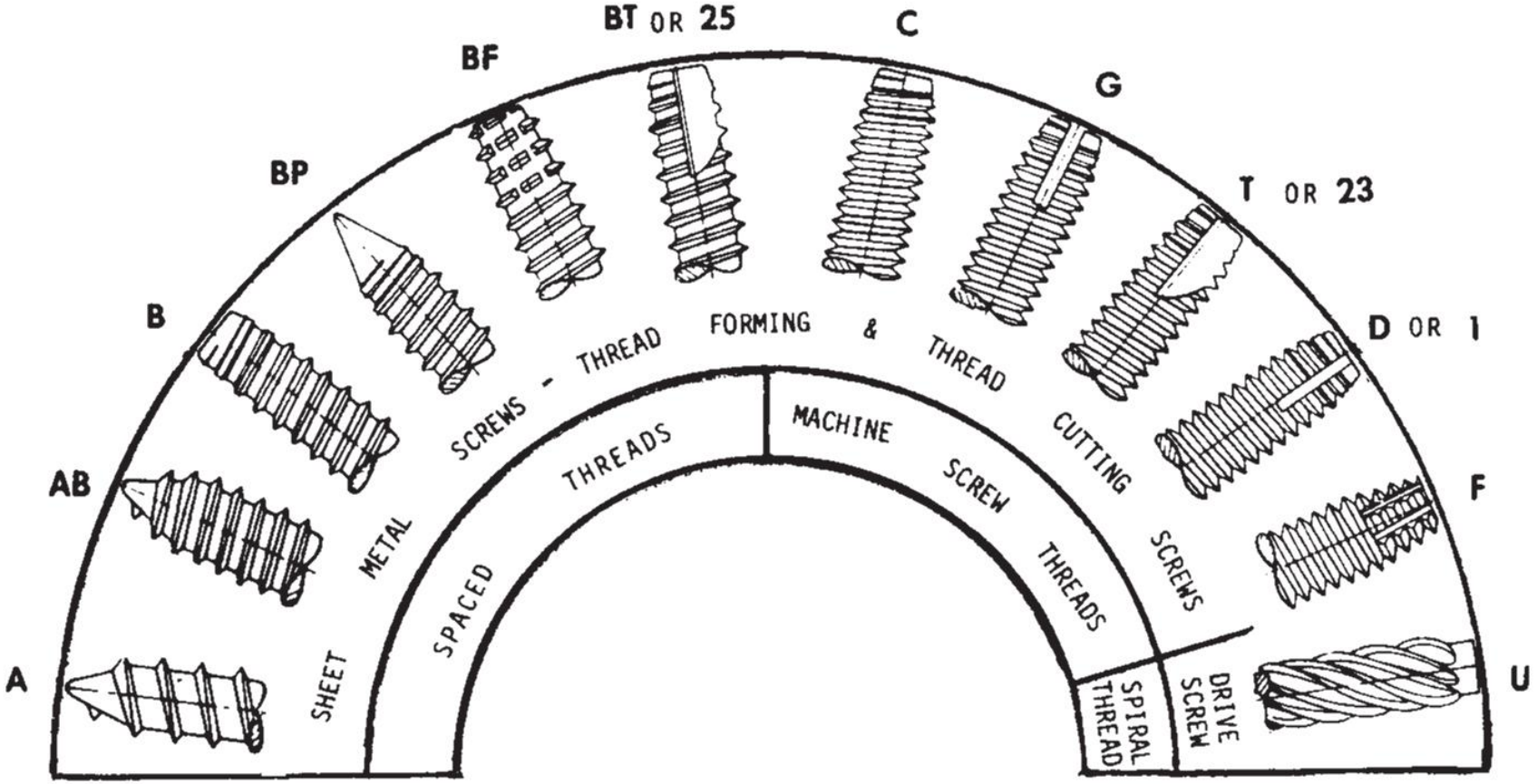
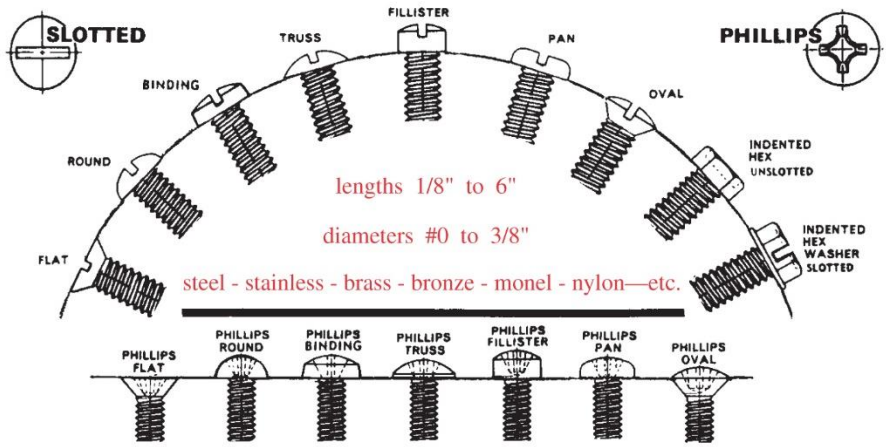


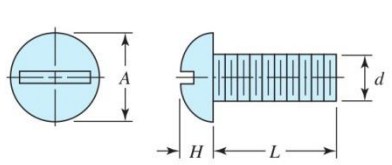
Figure 5

Threads Used on Tapping Screws

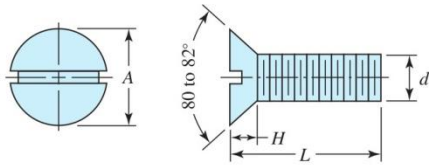


Classification by Head Type for Small Machine Screws

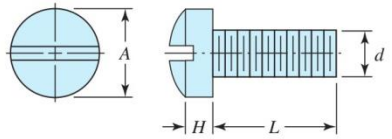




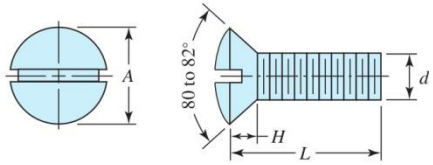
(*a*) Round head



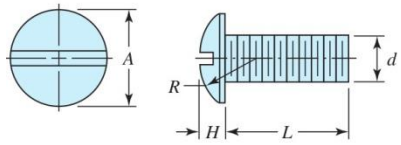
(*b*) Flat head



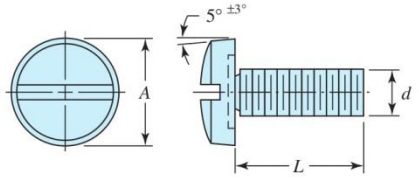
(*c*) Fillister head



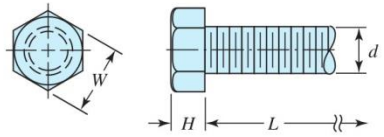
(*d*) Oval head



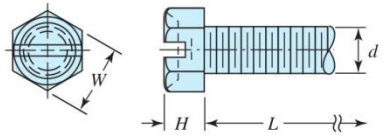
(*e*) Truss head



(*f*) Binding head



(*g*) Hex head (trimmed)

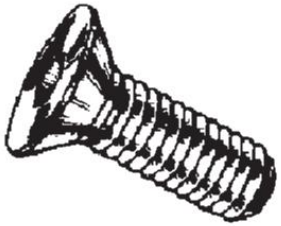


(*h*) Hex head (upset)

Styles of Socket-Head Cap Screws



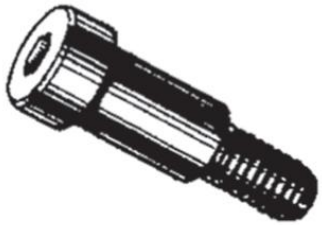
(*a*) Socket head



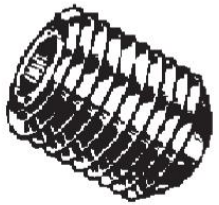
(*b*) Socket flat head



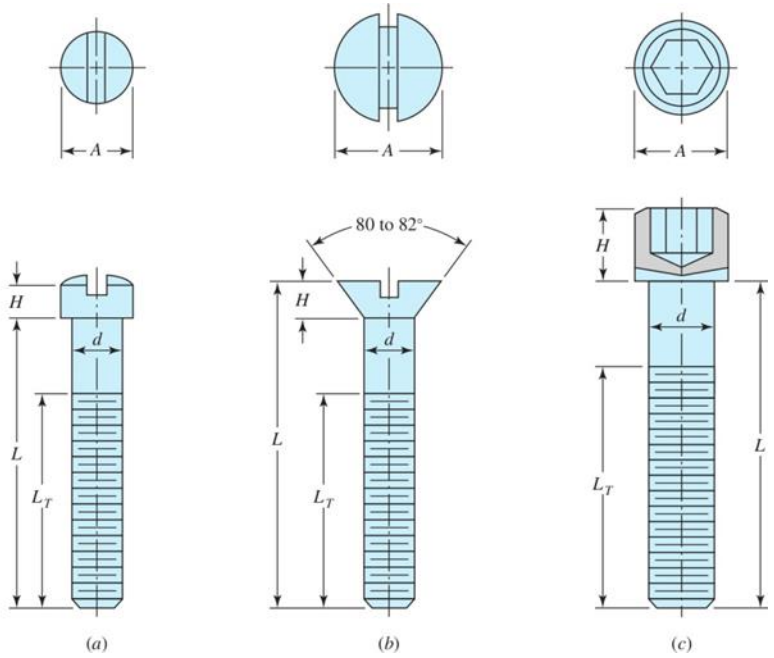
(*c*) Socket button head



(*d*) Shoulder screw



(*e*) Socket set screw



Classification of Nut



(a) Standard hex nut

Standard Nut



(d) Hex acorn nut

Decorative purposes



(b) Hex jam nut

Used in combination with the Standard Nut to lock it in place



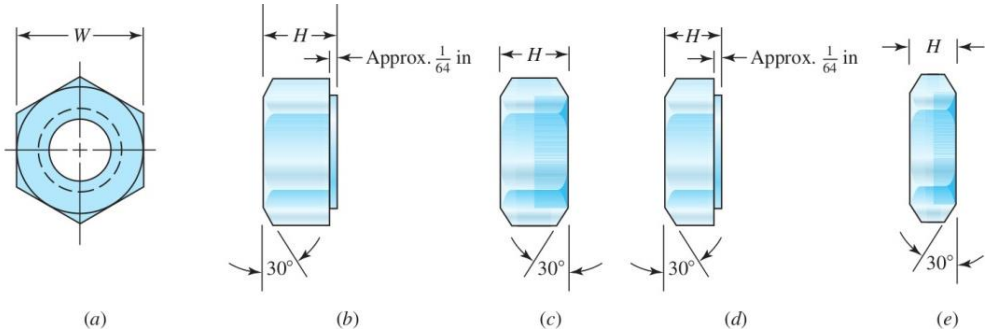
(e) Wing nut

Allows removal without tools



(c) Hex castle nut

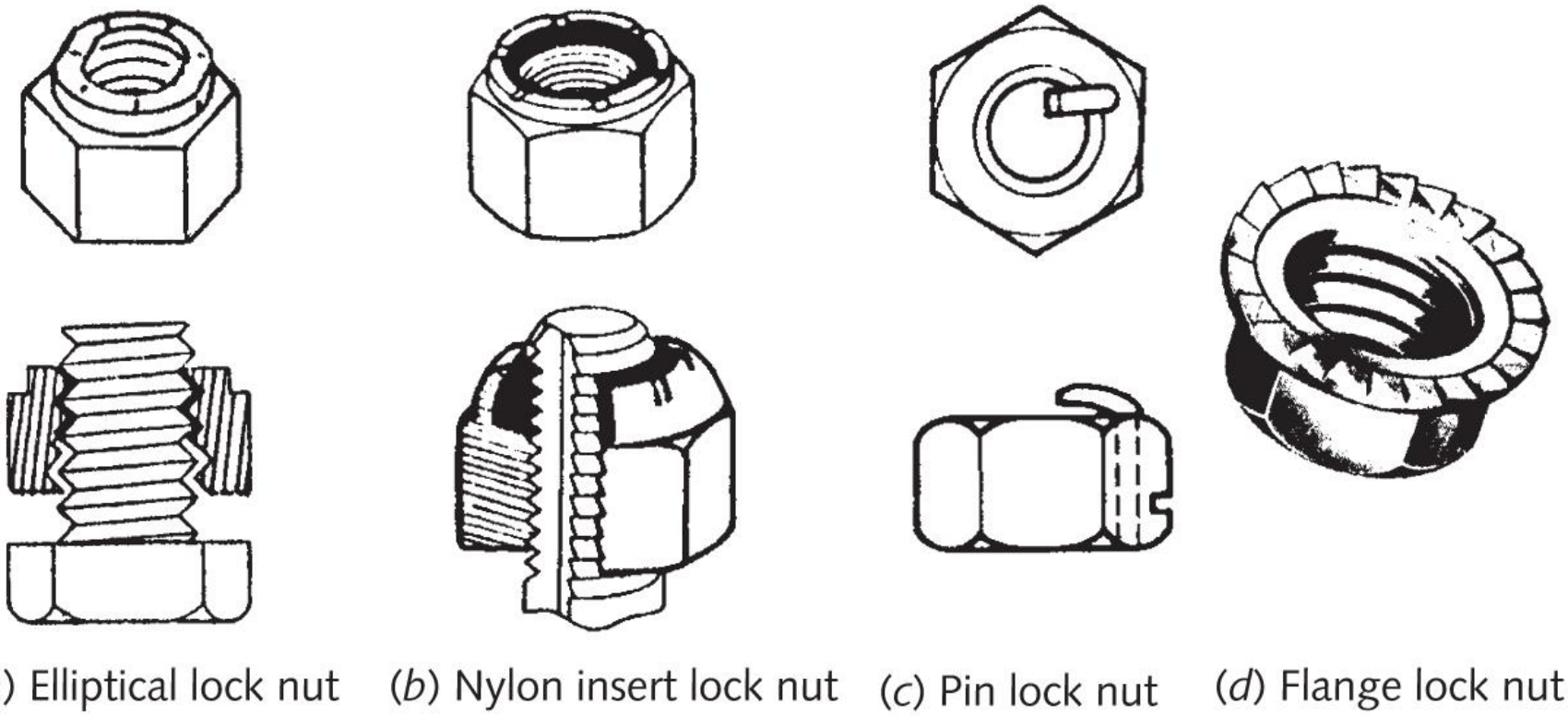
Groves are for insertion of a cotter pin through bolt to prevent loosening



Hexagonal Nut Dimensions

Nominal Size, in	Width *W*	Height *H*		
		Regular Hexagonal	Thick or Slotted	JAM
$\frac{1}{4}$	$\frac{7}{16}$	$\frac{7}{32}$	$\frac{9}{32}$	$\frac{5}{32}$
$\frac{5}{16}$	$\frac{1}{2}$	$\frac{17}{64}$	$\frac{21}{64}$	$\frac{3}{16}$
$\frac{3}{8}$	$\frac{9}{16}$	$\frac{21}{64}$	$\frac{13}{32}$	$\frac{7}{32}$
$\frac{7}{16}$	$\frac{11}{16}$	$\frac{3}{8}$	$\frac{29}{64}$	$\frac{1}{4}$
$\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{5}{16}$
$\frac{9}{16}$	$\frac{7}{8}$	$\frac{31}{64}$	$\frac{39}{64}$	$\frac{5}{16}$
$\frac{5}{8}$	$\frac{15}{16}$	$\frac{35}{64}$	$\frac{23}{32}$	$\frac{3}{8}$
$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{41}{64}$	$\frac{13}{16}$	$\frac{27}{64}$
$\frac{7}{8}$	$1\frac{5}{16}$	$\frac{3}{4}$	$\frac{29}{32}$	$\frac{31}{64}$
1	$1\frac{1}{2}$	$\frac{55}{64}$	1	$\frac{35}{64}$
$1\frac{1}{8}$	$1\frac{11}{16}$	$\frac{31}{32}$	$1\frac{5}{32}$	$\frac{39}{64}$
$1\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$\frac{23}{32}$
$1\frac{3}{8}$	$2\frac{1}{16}$	$1\frac{11}{64}$	$1\frac{3}{8}$	$\frac{25}{32}$
$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{9}{32}$	$1\frac{1}{2}$	$\frac{27}{32}$

Locking Nuts
Prevent Loosening of nut due to Vibration



(*a*) Elliptical lock nut (*b*) Nylon insert lock nut (*c*) Pin lock nut (*d*) Flange lock nut

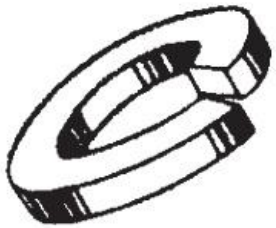
Washers



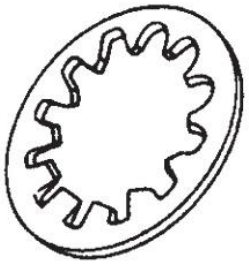
Standard Washer
Rounded edge should face bolt head. Made of hardened steel to distribute pressure under bolt head



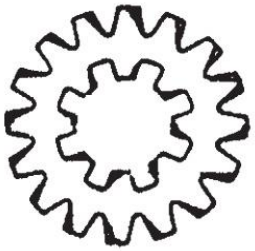
Belleville Washer
Controls axial load over changes in clamping length. Used under the nub or screw head



Split Lock Washer
Acts like a spring under the Nut









Toothed Washer
Turned up teeth are designed to dig into the nut or part surface

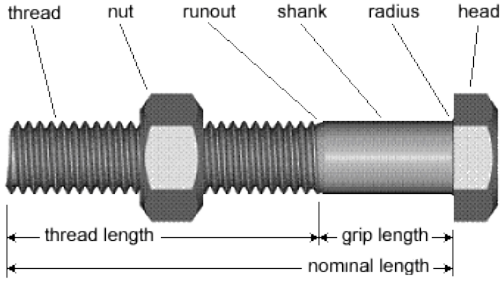
Dimensions of Standard Plain Washers

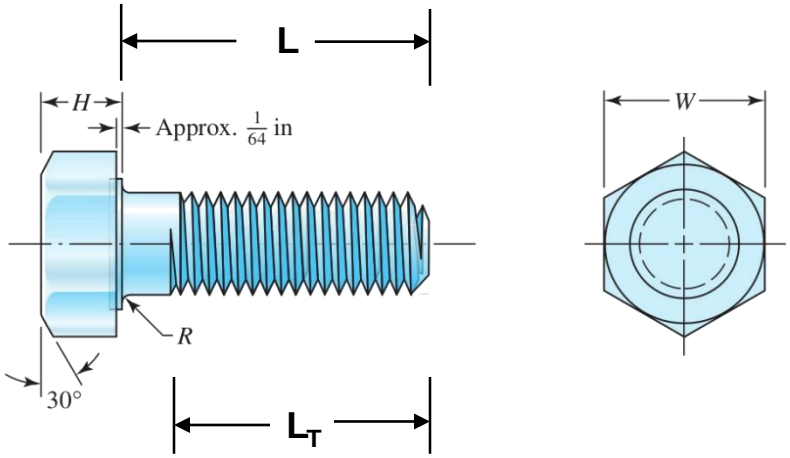
(All Dimensions in Inches)

Fastener Size	Washer Size	Diameter		Thickness
		ID	OD	
#6	0.138	0.156	0.375	0.049
#8	0.164	0.188	0.438	0.049
#10	0.190	0.219	0.500	0.049
#12	0.216	0.250	0.562	0.065
$\frac{1}{4}$ N	0.250	0.281	0.625	0.065
$\frac{1}{4}$ W	0.250	0.312	0.734	0.065
$\frac{5}{16}$ N	0.312	0.344	0.688	0.065
$\frac{5}{16}$ W	0.312	0.375	0.875	0.083
$\frac{3}{8}$ N	0.375	0.406	0.812	0.065
$\frac{3}{8}$ W	0.375	0.438	1.000	0.083
$\frac{7}{16}$ N	0.438	0.469	0.922	0.065
$\frac{7}{16}$ W	0.438	0.500	1.250	0.083
$\frac{1}{2}$ N	0.500	0.531	1.062	0.095

Hexagonal-Head Bolts and Hexagonal Cap Screws

- **Stress Concentrations**
  - **Fillet**
  - **Start of Thread (runout)**
  - **Thread-Root fillet in the plane of the nut (when present)**
- **Diameter of washer, same as width across flats of hexagon.**
- **d is the nominal diameter**
- **Ideal length would see one to two threads projecting out of the nut**
- **Hold the bolt head stationary and twist the nut**
- **Cap Screw head slightly thinner than bolt**





$$L_T = \begin{cases} 2 \cdot d + \frac{1}{4} in & L \le 6in \\ 2 \cdot d + \frac{1}{2} in & L \ge 6in \end{cases}$$

$$L_T = \begin{cases} 2 \cdot d + 6mm & L \le 125mm \quad d \le 48mm \\ 2 \cdot d + 12mm & 125 < L \le 200mm \\ 2 \cdot d + 25mm & L > 200mm \end{cases}$$

Preferred Sizes

Fraction of Inches

$\frac{1}{64}$, $\frac{1}{32}$, $\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$, $\frac{11}{16}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3,

$3\frac{1}{4}$, $3\frac{1}{2}$, $3\frac{3}{4}$, 4, $4\frac{1}{4}$, $4\frac{1}{2}$, $4\frac{3}{4}$, 5, $5\frac{1}{4}$, $5\frac{1}{2}$, $5\frac{3}{4}$, 6, $6\frac{1}{2}$, 7, $7\frac{1}{2}$, 8, $8\frac{1}{2}$, 9, $9\frac{1}{2}$, 10, $10\frac{1}{2}$, 11, $11\frac{1}{2}$, 12,

$12\frac{1}{2}$, 13, $13\frac{1}{2}$, 14, $14\frac{1}{2}$, 15, $15\frac{1}{2}$, 16, $16\frac{1}{2}$, 17, $17\frac{1}{2}$, 18, $18\frac{1}{2}$, 19, $19\frac{1}{2}$, 20

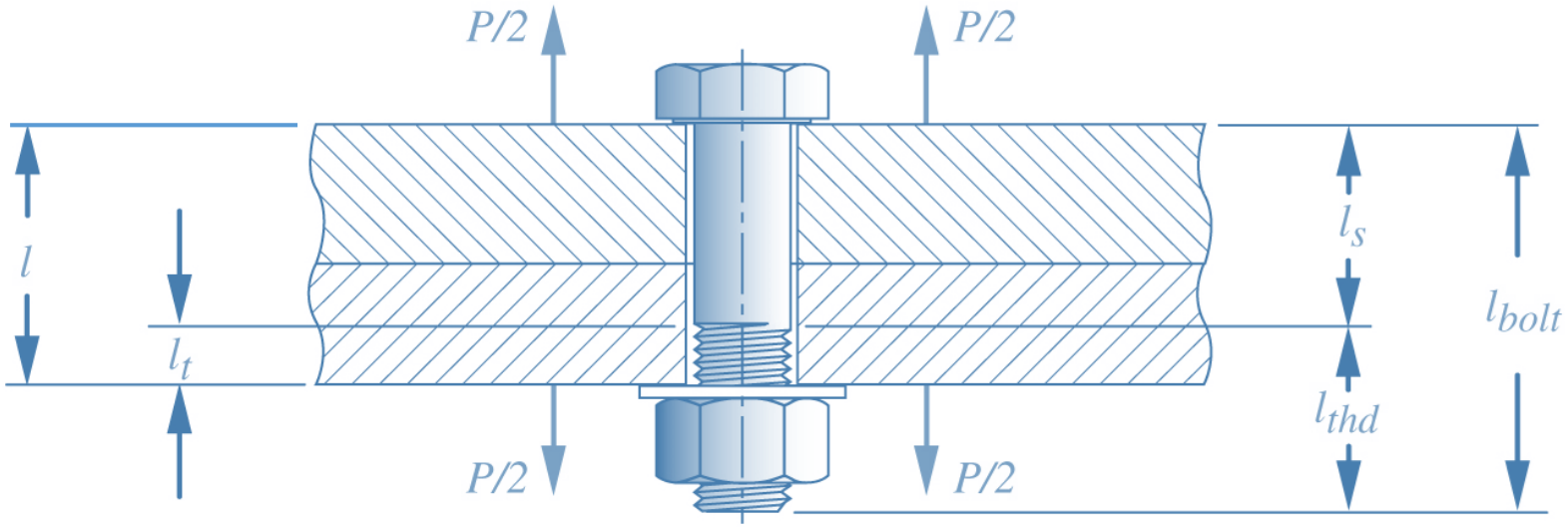
Decimal Inches

0.010, 0.012, 0.016, 0.020, 0.025, 0.032, 0.040, 0.05, 0.06, 0.08, 0.10, 0.12, 0.16, 0.20, 0.24, 0.30, 0.40, 0.50, 0.60, 0.80, 1.00, 1.20, 1.40, 1.60, 1.80, 2.0, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, 5.2, 5.4, 5.6, 5.8, 6.0, 7.0, 7.5, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20

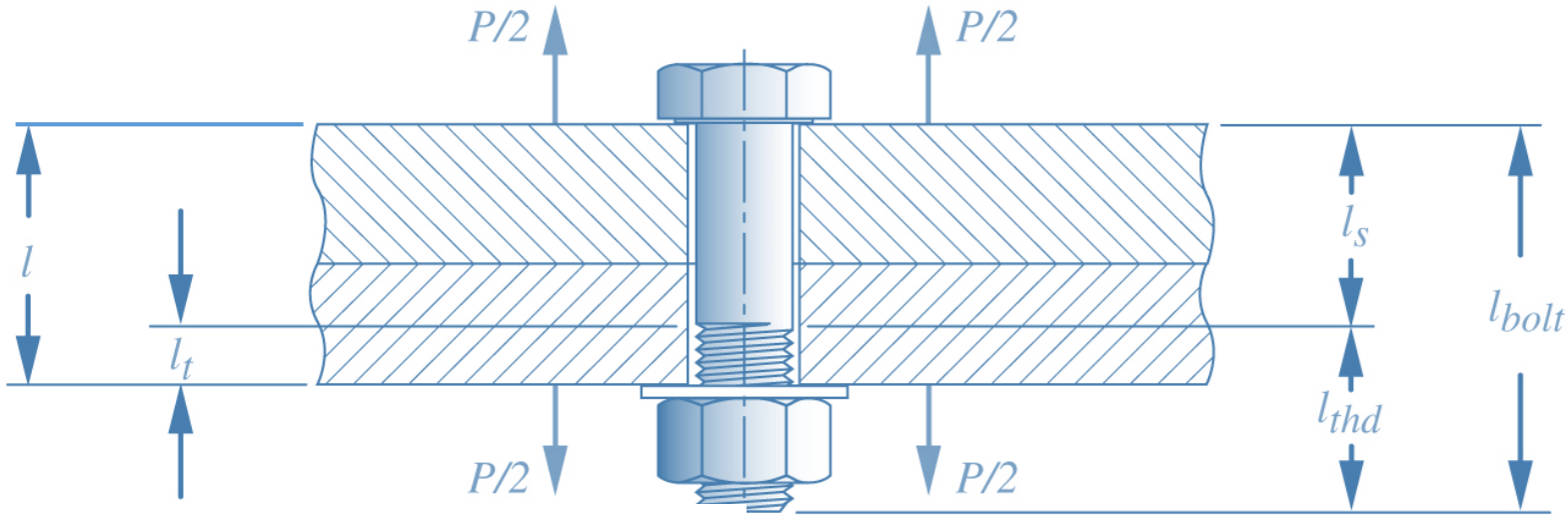
Millimeters

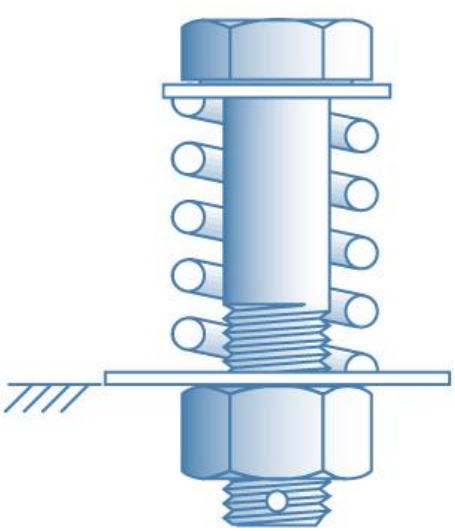
0.05, 0.06, 0.08, 0.10, 0.12, 0.16, 0.20, 0.25, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.0, 1.1, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0, 2.2, 2.5, 2.8, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 9.0, 10, 11, 12, 14, 16, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50, 60, 80, 100, 120, 140, 160, 180, 200, 250, 300

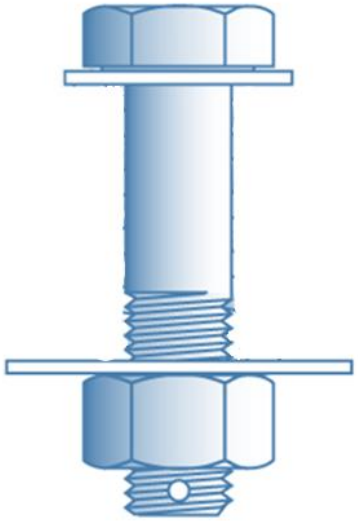
Understanding Joint Mechanics

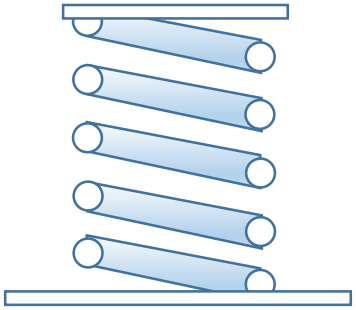


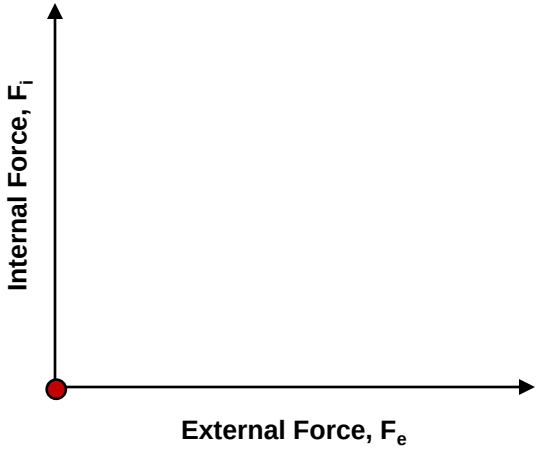
Understanding Joint Mechanics



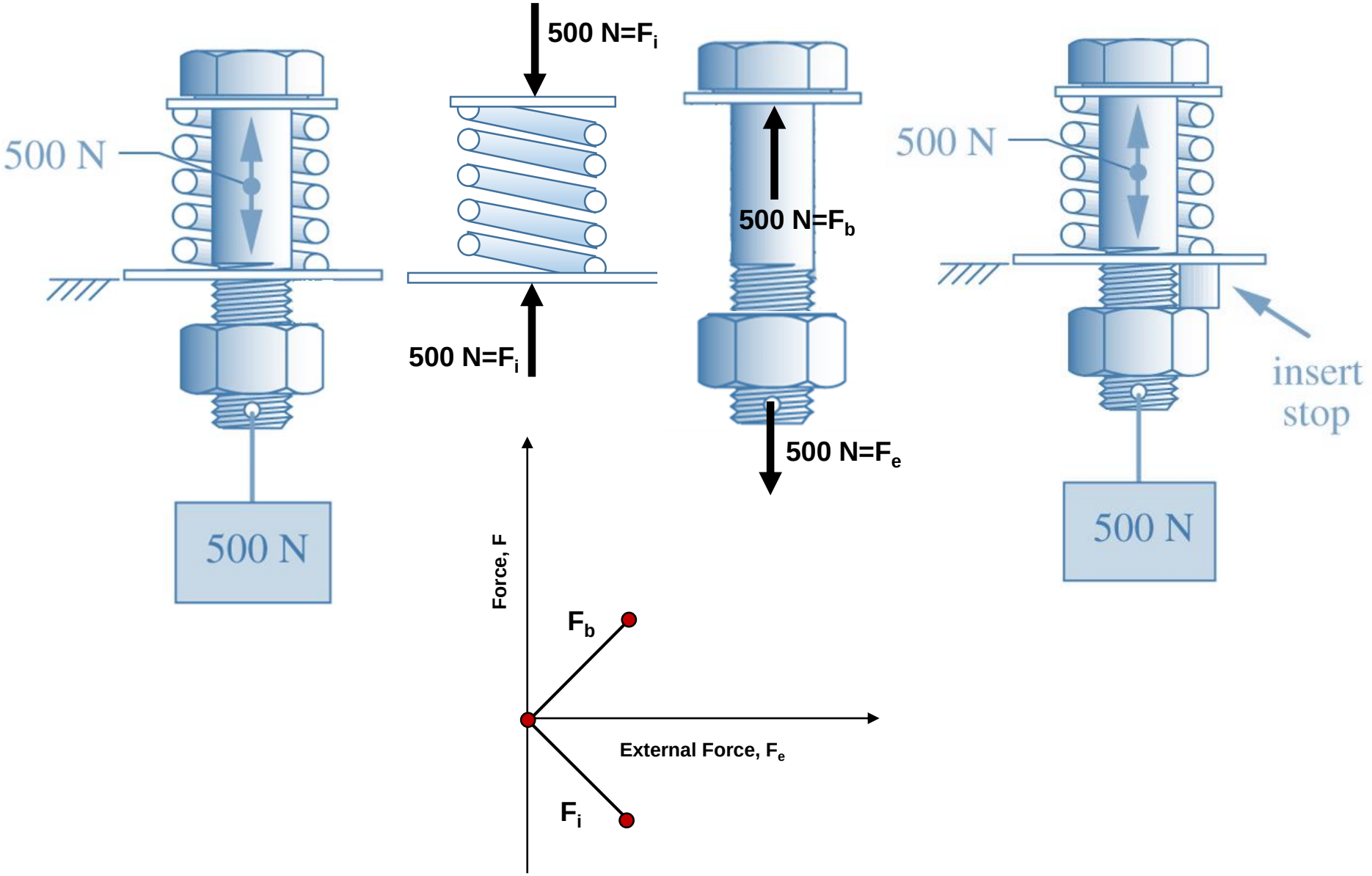




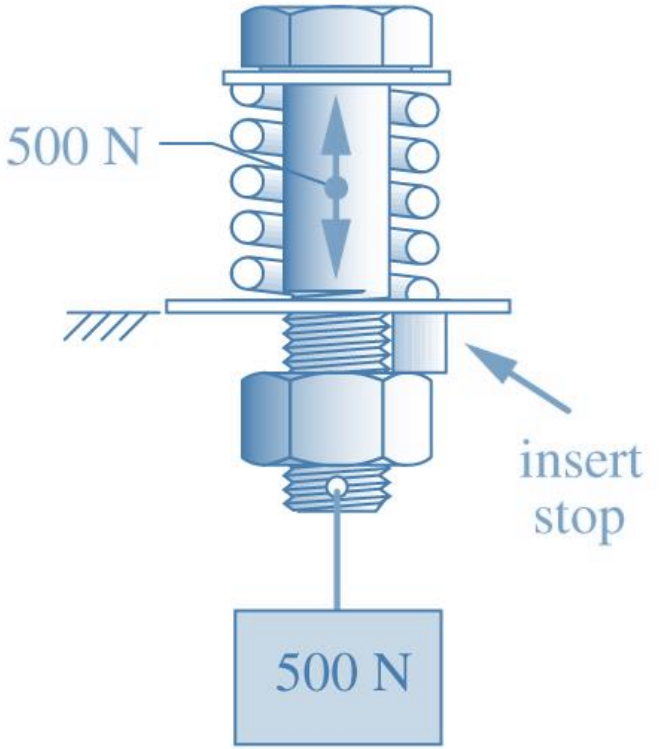


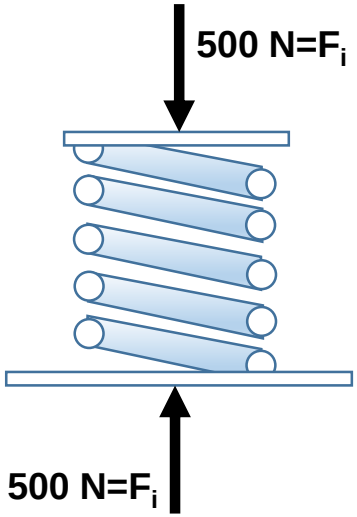


Adding a 500 N Pre-Load

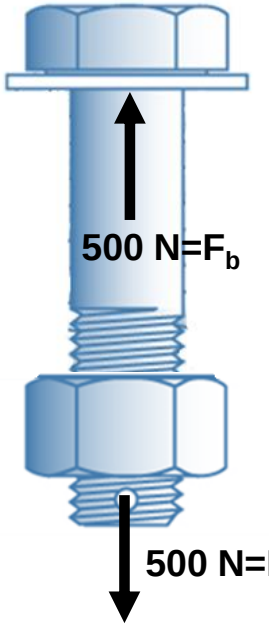


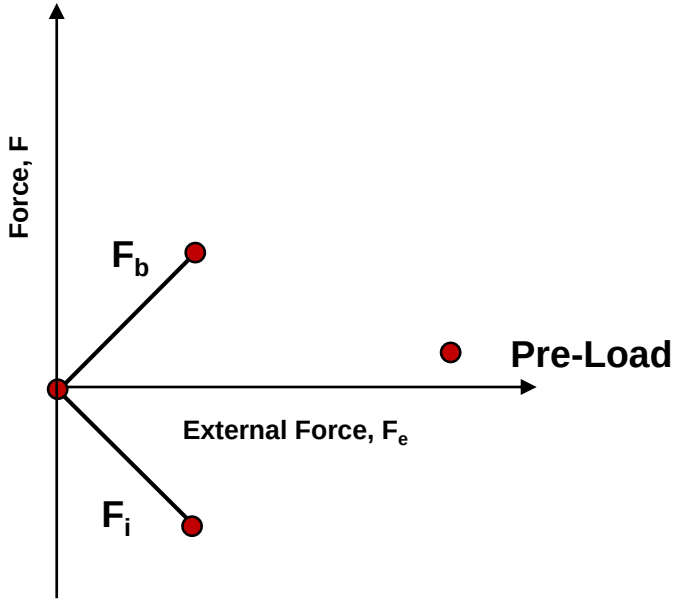
Adding a 500 N Pre-Load



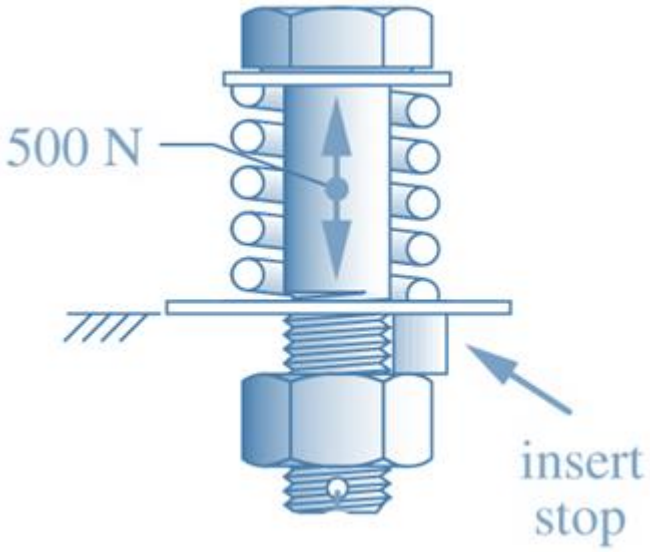


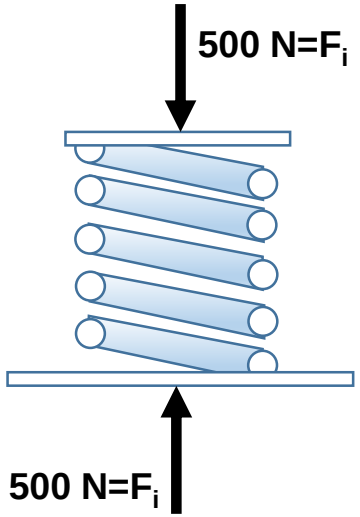
0 N=F_s

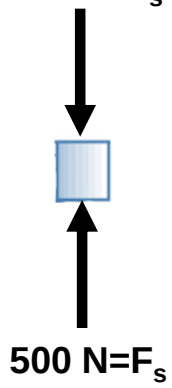


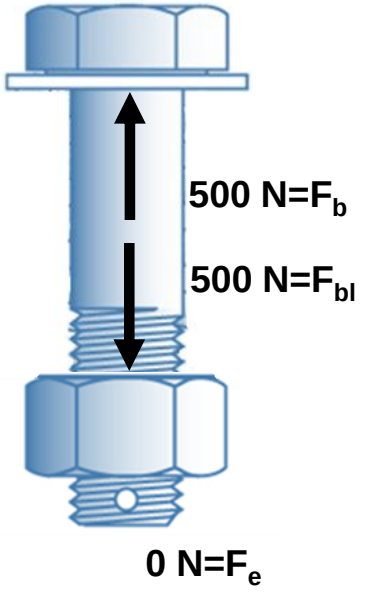


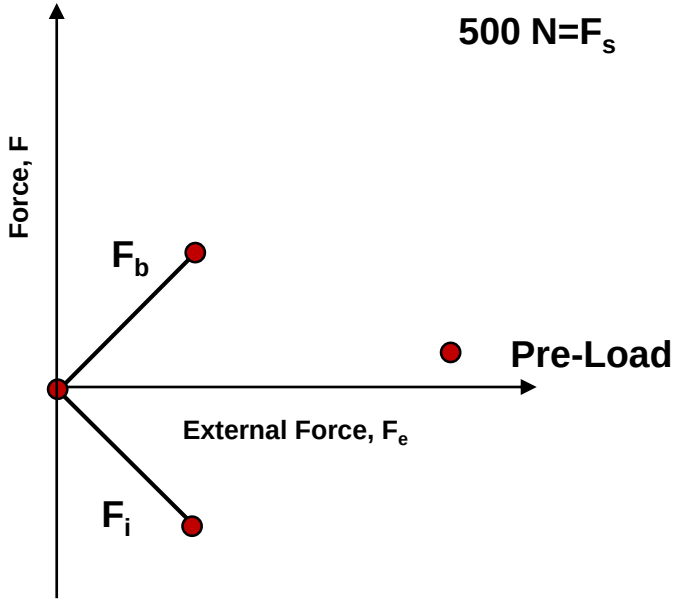
Adding a 500 N Pre-Load



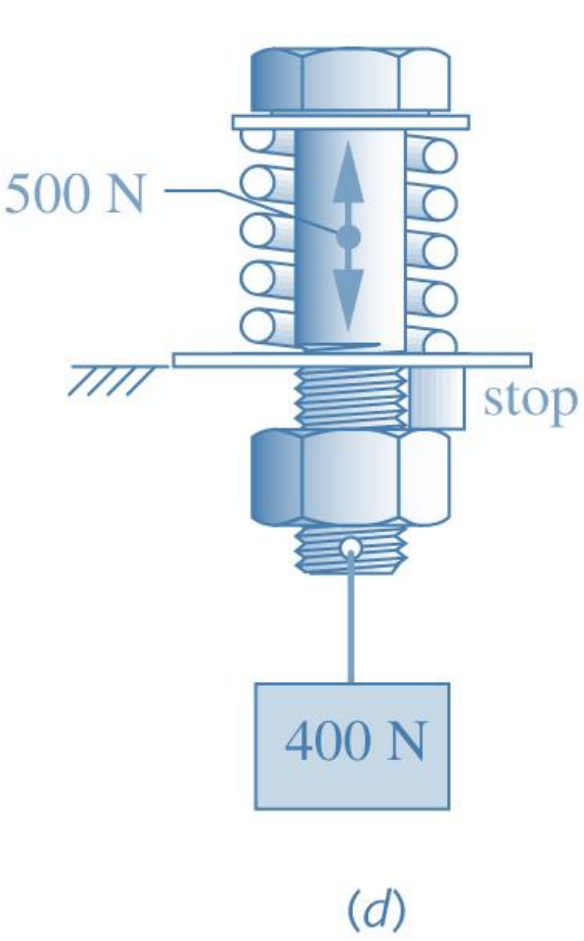


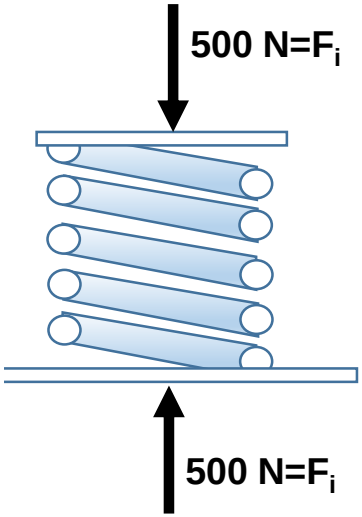


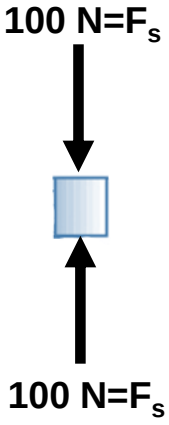


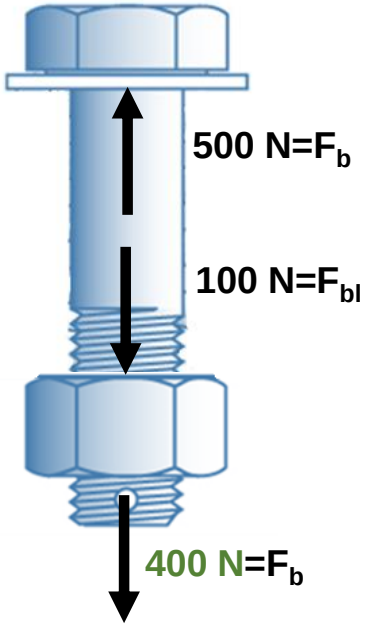


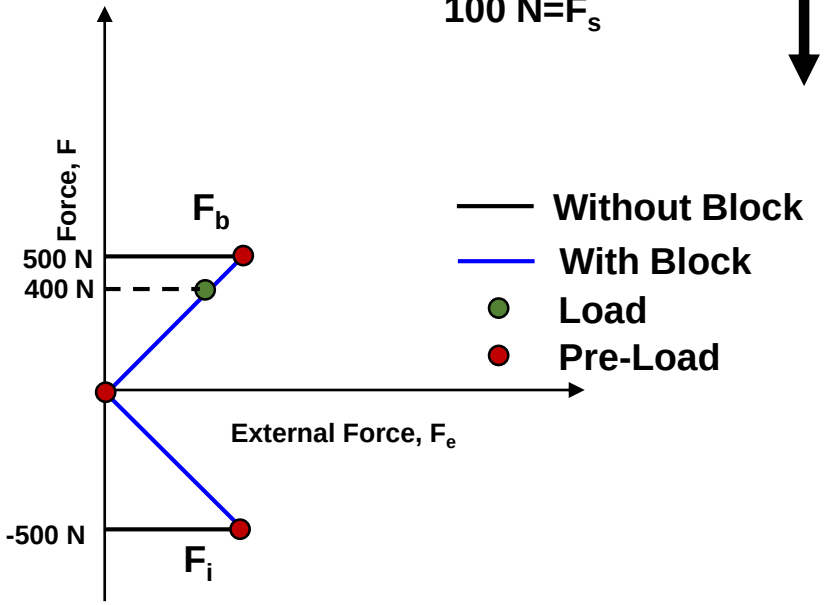
w/ Block and 400 N External Load



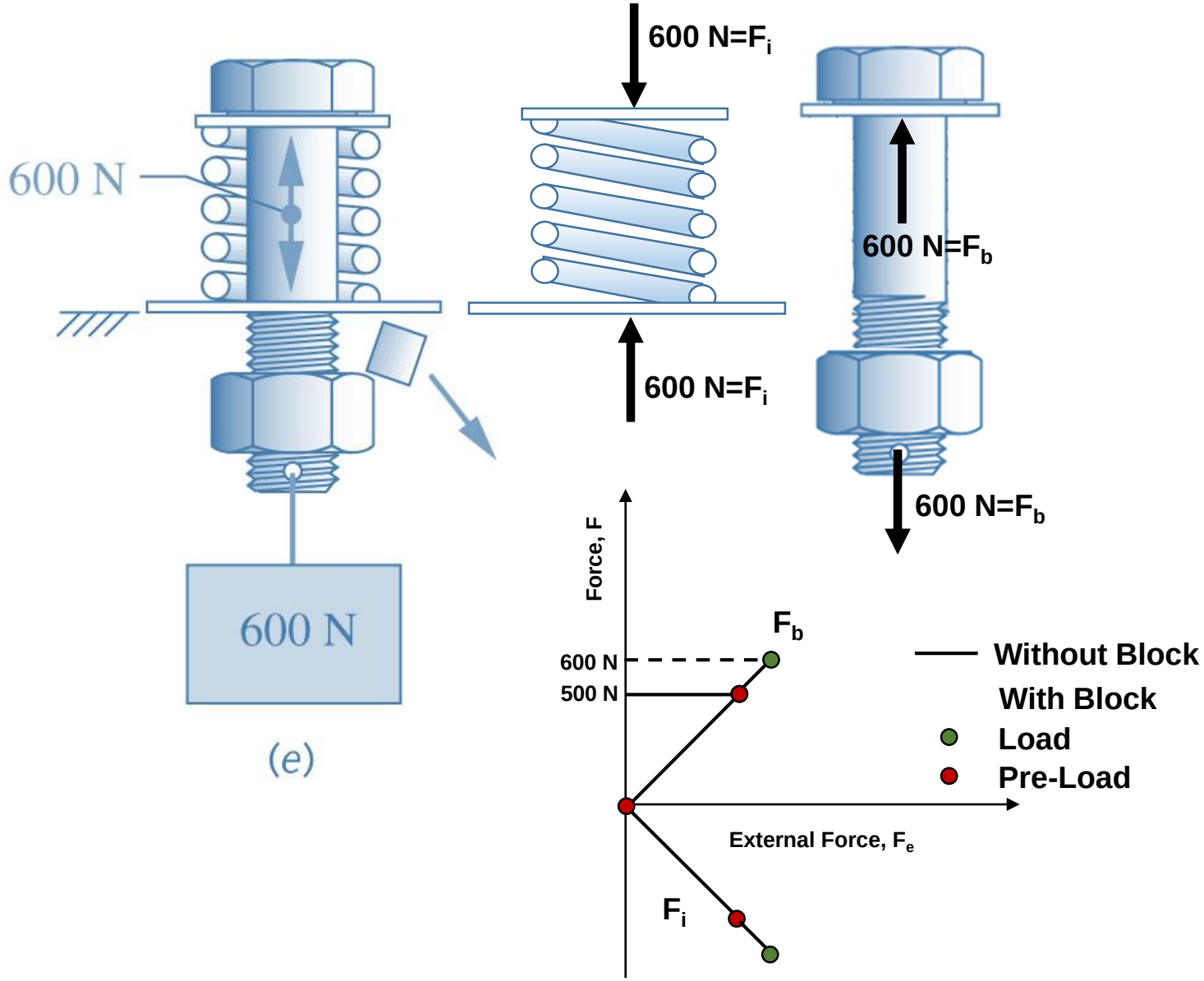








w/ Block and 600 N External Load



Tightening and Initial Tension

$F_i = K_i \cdot A_t \cdot S_p \approx 0.9 \cdot A_t \cdot S_p$

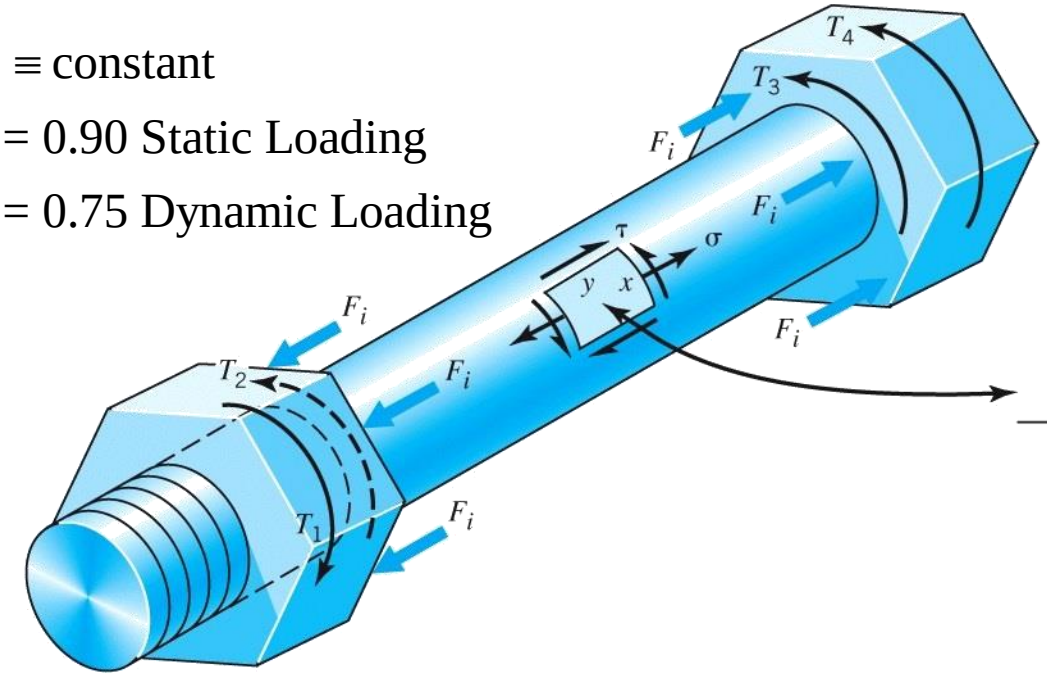
$A_t \equiv$ Tensile Area

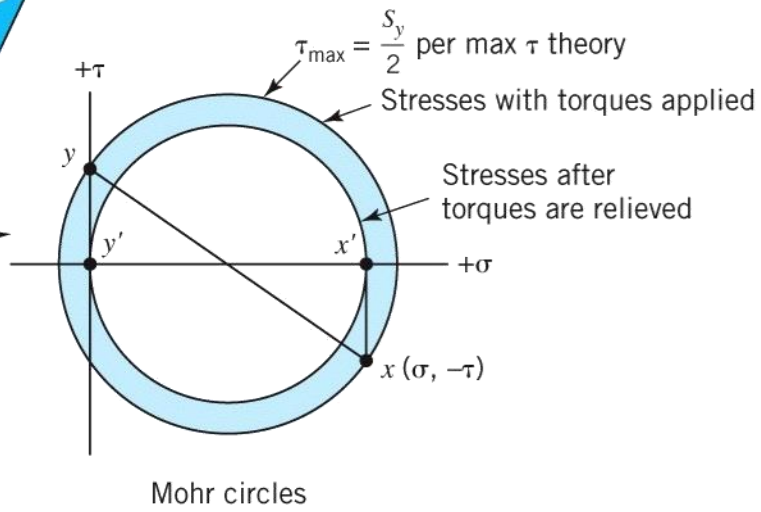
$S_p \equiv$ Proof Load

$K_i \equiv$ constant

= 0.90 Static Loading

= 0.75 Dynamic Loading

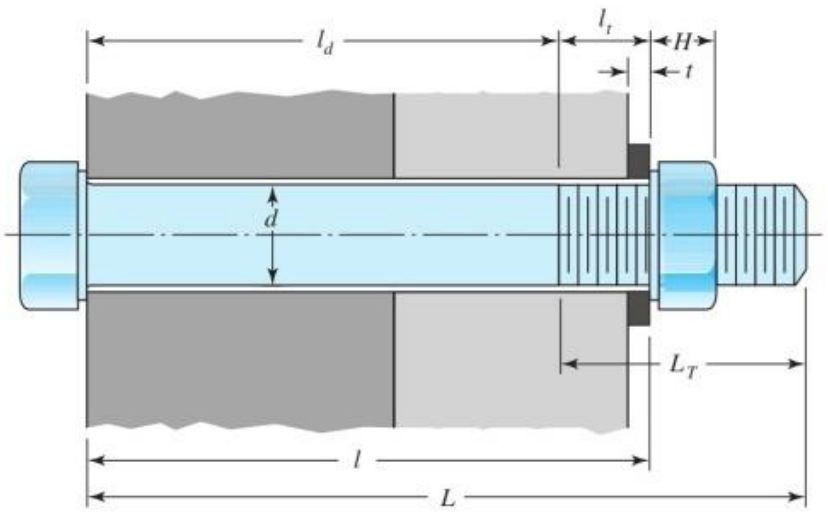


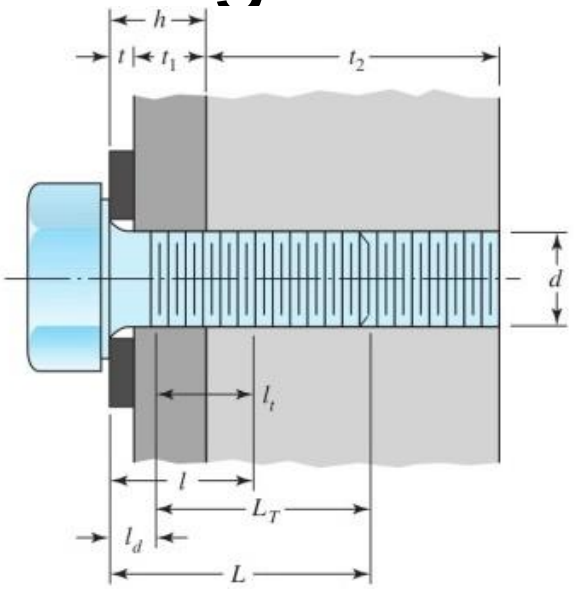


Rational for High Initial Tension in Bolt

1. Tensile Loading: Bolt loads cannot increase very much unless members separate
2. Shear Loading: The higher the initial tension, the higher the friction forces

Fastener Sizing





Bolt Grip Length:

$l =$ Thickness of material between Face of Bolt and Face of Nut

Screw Grip Length: $l = \begin{cases} h + t_2/2, & t_2 < d \\ h + d/2, & t_2 \geq d \end{cases}$

Thread Length

$$L_T = \begin{cases} 2 \cdot d + \frac{1}{4} in & L \leq 6in \\ 2 \cdot d + \frac{1}{2} in & L \geq 6in \end{cases}$$

$$L_T = \begin{cases} 2 \cdot d + 6mm & L \leq 125mm \quad d \leq 48mm \\ 2 \cdot d + 12mm & 125 < L \leq 200mm \\ 2 \cdot d + 25mm & L > 200mm \end{cases}$$

Fastener Length using Prefered Sizes

Bolt: $L > l + H$

Screw: $L > h + 1.5d$

Example

Determine an appropriate 5/16-18 Bolt Size for the configuration shown.

Table A-31: Dimensions of Hex Nuts

Table A-32: Plain Washer Dimensions (inches)

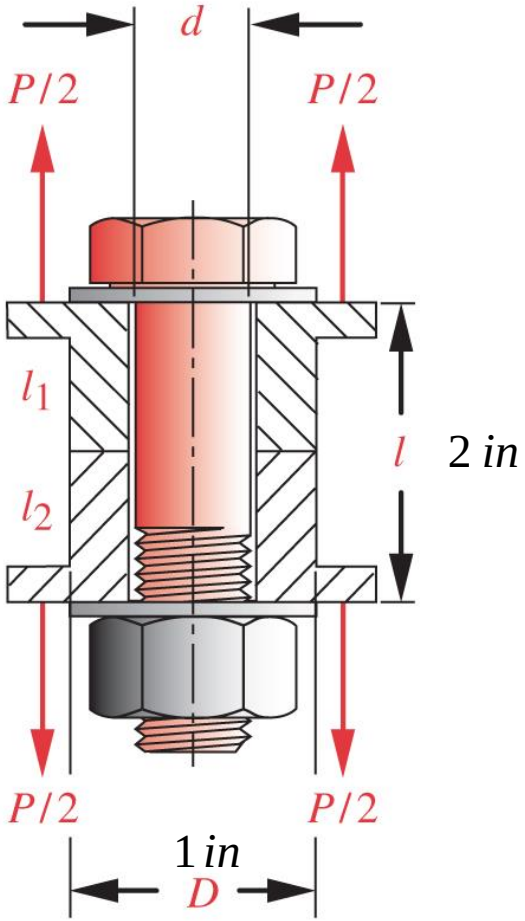


Table A–32

Basic Dimensions of American Standard Plain Washers (All Dimensions in Inches)

Fastener Size	Washer Size	Diameter ID	Diameter OD	Thickness
#6	0.138	0.156	0.375	0.049
#8	0.164	0.188	0.438	0.049
#10	0.190	0.219	0.500	0.049
#12	0.216	0.250	0.562	0.065
$\frac{1}{4}$ N	0.250	0.281	0.625	0.065
$\frac{1}{4}$ W	0.250	0.312	0.734	0.065
$\frac{5}{16}$ N	0.312	0.344	0.688	0.065
$\frac{5}{16}$ W	0.312	0.375	0.875	0.083
$\frac{3}{8}$ N	0.375	0.406	0.812	0.065
$\frac{3}{8}$ W	0.375	0.438	1.000	0.083
$\frac{7}{16}$ N	0.438	0.469	0.922	0.065
$\frac{7}{16}$ W	0.438	0.500	1.250	0.083
$\frac{1}{2}$ N	0.500	0.531	1.062	0.095

N = narrow; W = wide; use W when not specified.

Table A–31

Dimensions of Hexagonal Nuts

Nominal Size, in	Width *W*	Height *H*		
		Regular Hexagonal	Thick or Slotted	JAM
$\frac{1}{4}$	$\frac{7}{16}$	$\frac{7}{32}$	$\frac{9}{32}$	$\frac{5}{32}$
$\frac{5}{16}$	$\frac{1}{2}$	$\frac{17}{64}$	$\frac{21}{64}$	$\frac{3}{16}$
$\frac{3}{8}$	$\frac{9}{16}$	$\frac{21}{64}$	$\frac{13}{32}$	$\frac{7}{32}$
$\frac{7}{16}$	$\frac{11}{16}$	$\frac{3}{8}$	$\frac{29}{64}$	$\frac{1}{4}$
$\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{5}{16}$
$\frac{9}{16}$	$\frac{7}{8}$	$\frac{31}{64}$	$\frac{39}{64}$	$\frac{5}{16}$
$\frac{5}{8}$	$\frac{15}{16}$	$\frac{35}{64}$	$\frac{23}{32}$	$\frac{3}{8}$
$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{41}{64}$	$\frac{13}{16}$	$\frac{27}{64}$
$\frac{7}{8}$	$1\frac{5}{16}$	$\frac{3}{4}$	$\frac{29}{32}$	$\frac{31}{64}$
1	$1\frac{1}{2}$	$\frac{55}{64}$	1	$\frac{35}{64}$
$1\frac{1}{8}$	$1\frac{11}{16}$	$\frac{31}{32}$	$1\frac{5}{32}$	$\frac{39}{64}$
$1\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$\frac{23}{32}$
$1\frac{3}{8}$	$2\frac{1}{16}$	$1\frac{11}{64}$	$1\frac{3}{8}$	$\frac{25}{32}$
$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{9}{32}$	$1\frac{1}{2}$	$\frac{27}{32}$

Solution

Bolt Grip Length:

$l =$ Thickness of material between Face of Bolt and Face of Nut

Fastener Size	Washer Size	Diameter ID	Diameter OD	Thickness
$\frac{5}{16}$ N	0.312	0.344	0.688	0.065
$\frac{5}{16}$ W	0.312	0.375	0.875	0.083

$$l = 2\,in + 2\cdot(0.083\,in) = 2.166\,in$$

Thread Length

$$L_T = 2\cdot d + \tfrac{1}{4}\,in \quad L \le 6in$$

$$= 2\cdot\frac{5}{16}\,in + \frac{1}{4}\,in = \frac{14}{16}\,in = \frac{7}{8}\,in$$

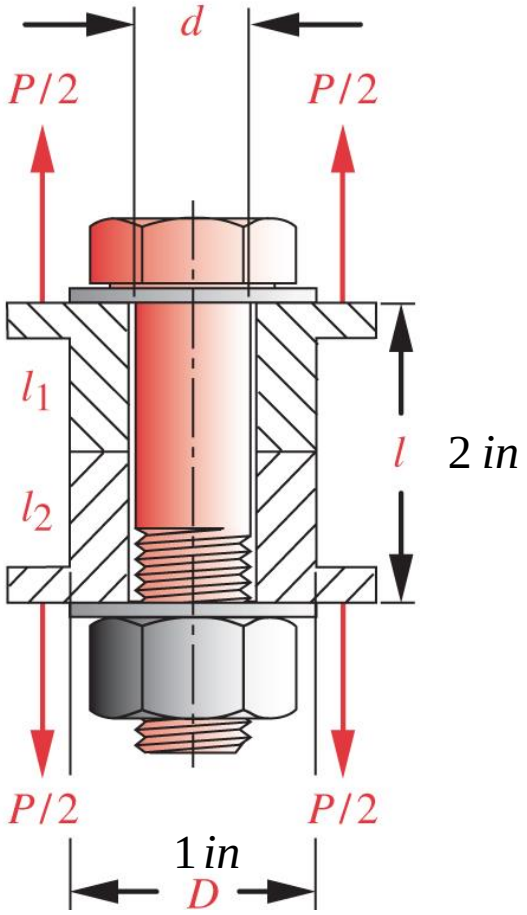
Fastener Length using Prefered Sizes

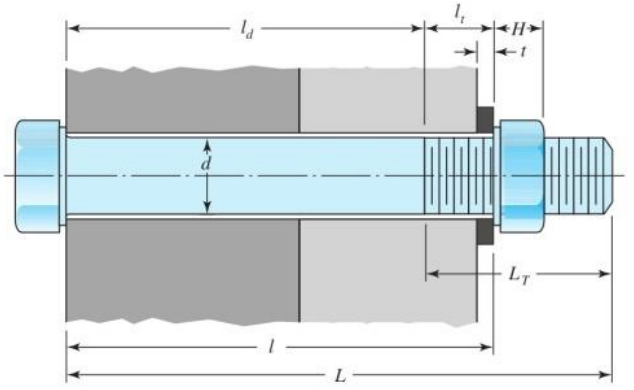
Bolt: $L > l + H = 2.166\,in + {}^{17}\!/_{64}\,in = 2.431\,in \Rightarrow 2.5\,in$

Nominal Size, in	Width W	Height H Regular Hexagonal	Height H Thick or Slotted	Height H JAM
$\frac{1}{4}$	$\frac{7}{16}$	$\frac{7}{32}$	$\frac{9}{32}$	$\frac{5}{32}$
$\frac{5}{16}$	$\frac{1}{2}$	$\frac{17}{64}$	$\frac{21}{64}$	$\frac{3}{16}$

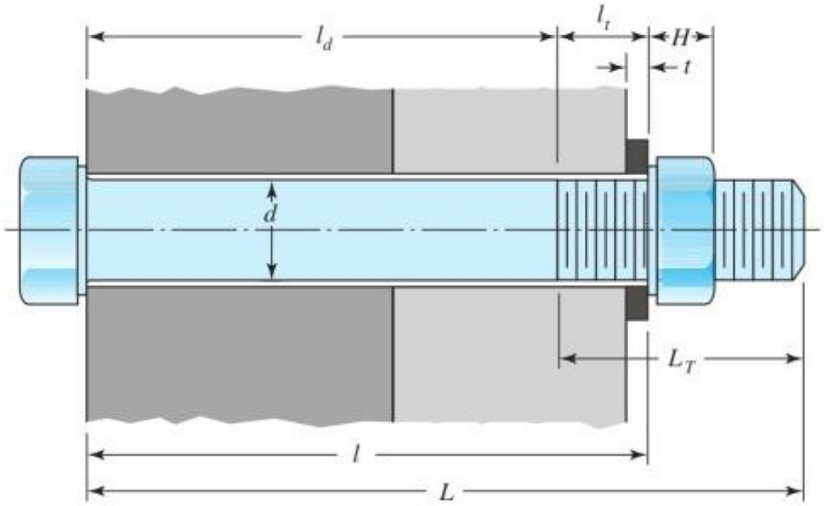
Fraction of Inches

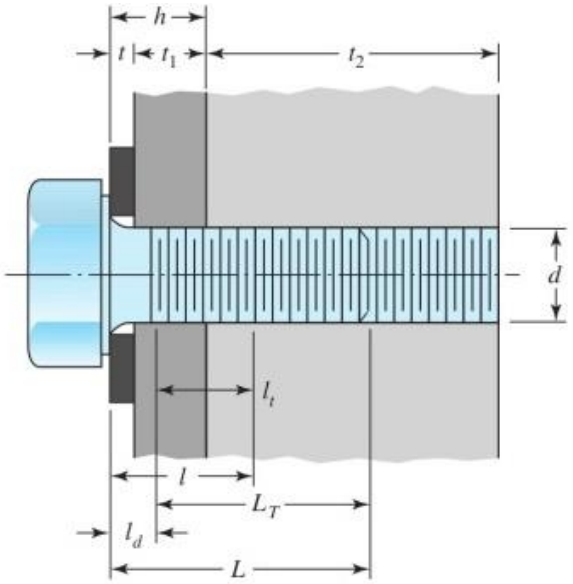
$\frac{1}{64}, \frac{1}{32}, \frac{1}{16}, \frac{3}{32}, \frac{1}{8}, \frac{5}{32}, \frac{3}{16}, \frac{1}{4}, \frac{5}{16}, \frac{3}{8}, \frac{7}{16}, \frac{1}{2}, \frac{9}{16}, \frac{5}{8}, \frac{11}{16}, \frac{3}{4}, \frac{7}{8}, 1, 1\frac{1}{4}, 1\frac{1}{2}, 1\frac{3}{4}, 2, 2\frac{1}{4}, 2\frac{1}{2}, 2\frac{3}{4}, 3,$





Calculating Fastener Stiffness





Tensile Stress Area of Threaded Portion in Grip

$$A_t = \frac{\pi}{2} \cdot \left(\frac{d_p + d_r}{2} \right)^2$$ Shigley 10th Table 8-1 Shigley 10th Table 8-2

UNS Threads

$$d_p = d - \left(\frac{0.649519}{N} \right)$$

$$d_r = d - \left(\frac{1.299038}{N} \right)$$

ISO Threads

$$d_p = d - 0.649519 \cdot p$$

$$d_r = d - 1.29903 \cdot p$$

$l_d = L - L_T$

≡ Length of unthreaded portion in grip

$l_t = l - l_d$

≡ Length of threaded portion in grip

$$k_b = \frac{A_d \cdot A_t \cdot E}{A_d \cdot l_t + A_t \cdot l_d}$$

≡ Fastener Stiffness

Example

Determine Fastener Stiffness for the 5/16-18 Bolt configuration shown.

From previous example
l = 2.166 in
L_T = 7/8 in = 0.875 in
L = 2.5 in

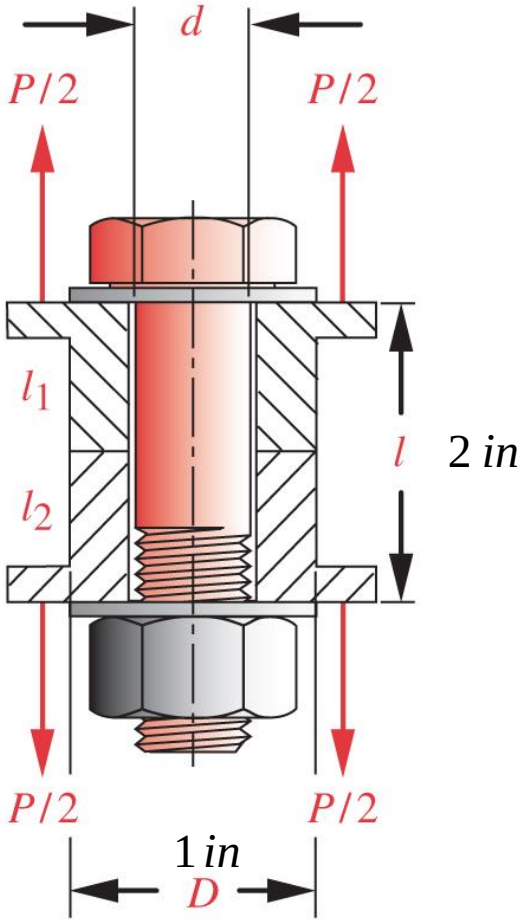


Table 8–2

Diameters and Area of Unified Screw Threads UNC and UNF*

Size Designation	Nominal Major Diameter in	Coarse Series—UNC Threads per Inch N	Coarse Series—UNC Tensile-Stress Area A_t in^2	Coarse Series—UNC Minor-Diameter Area A_r in^2	Fine Series—UNF Threads per Inch N	Fine Series—UNF Tensile-Stress Area A_t in^2	Fine Series—UNF Minor-Diameter Area A_r in^2
12	0.2160	24	0.024 2	0.020 6	28	0.025 8	0.022 6
$\frac{1}{4}$	0.2500	20	0.031 8	0.026 9	28	0.036 4	0.032 6
$\frac{5}{16}$	0.3125	18	0.052 4	0.045 4	24	0.058 0	0.052 4
$\frac{3}{8}$	0.3750	16	0.077 5	0.067 8	24	0.087 8	0.080 9
$\frac{7}{16}$	0.4375	14	0.106 3	0.093 3	20	0.118 7	0.109 0

Bolt Stiffness

Size Designation	Nominal Major Diameter in	Coarse Series—UNC Threads per Inch N	Coarse Series—UNC Tensile-Stress Area A_t in^2	Coarse Series—UNC Minor-Diameter Area A_r in^2	Fine Series—UNF Threads per Inch N	Fine Series—UNF Tensile-Stress Area A_t in^2	Fine Series—UNF Minor-Diameter Area A_r in^2
$\frac{5}{16}$	0.3125	18	0.052 4	0.045 4	24	0.058 0	0.052 4

Tensile Stress Area of Threaded Portion in Grip

$A_t = 0.0524\,in^2$

Tensile Stress Area of UnThreaded Portion of Fastener

$$A_d = \frac{\pi \cdot \left(\frac{5}{16}in\right)^2}{4} = 0.0767\,in^2$$

$l_d = L - L_T = 2.5in - 0.875\,in = 1.625in$

$\equiv$ Length of unthreaded portion in grip

$l_t = l - l_d = 2.166in - 1.625in = 0.541in$

$\equiv$ Length of threaded portion in grip

$$k_b = \frac{A_d \cdot A_t \cdot E}{A_d \cdot l_t + A_t \cdot l_d}$$

$$= \frac{\left(0.0767\,in^2\right)\cdot\left(0.0524in^2\right)\cdot\left(29x10^6\,\frac{lb}{in^2}\right)}{\left(0.0767\,in^2\right)\cdot\left(0.541in\right)+\left(0.0524in^2\right)\cdot\left(1.625in\right)}$$

$$= 920.3x10^3\,\frac{lb}{in^2}$$

