

# **Box Lewis**

## **MFG research notes and interim updates**

# **GOALS**

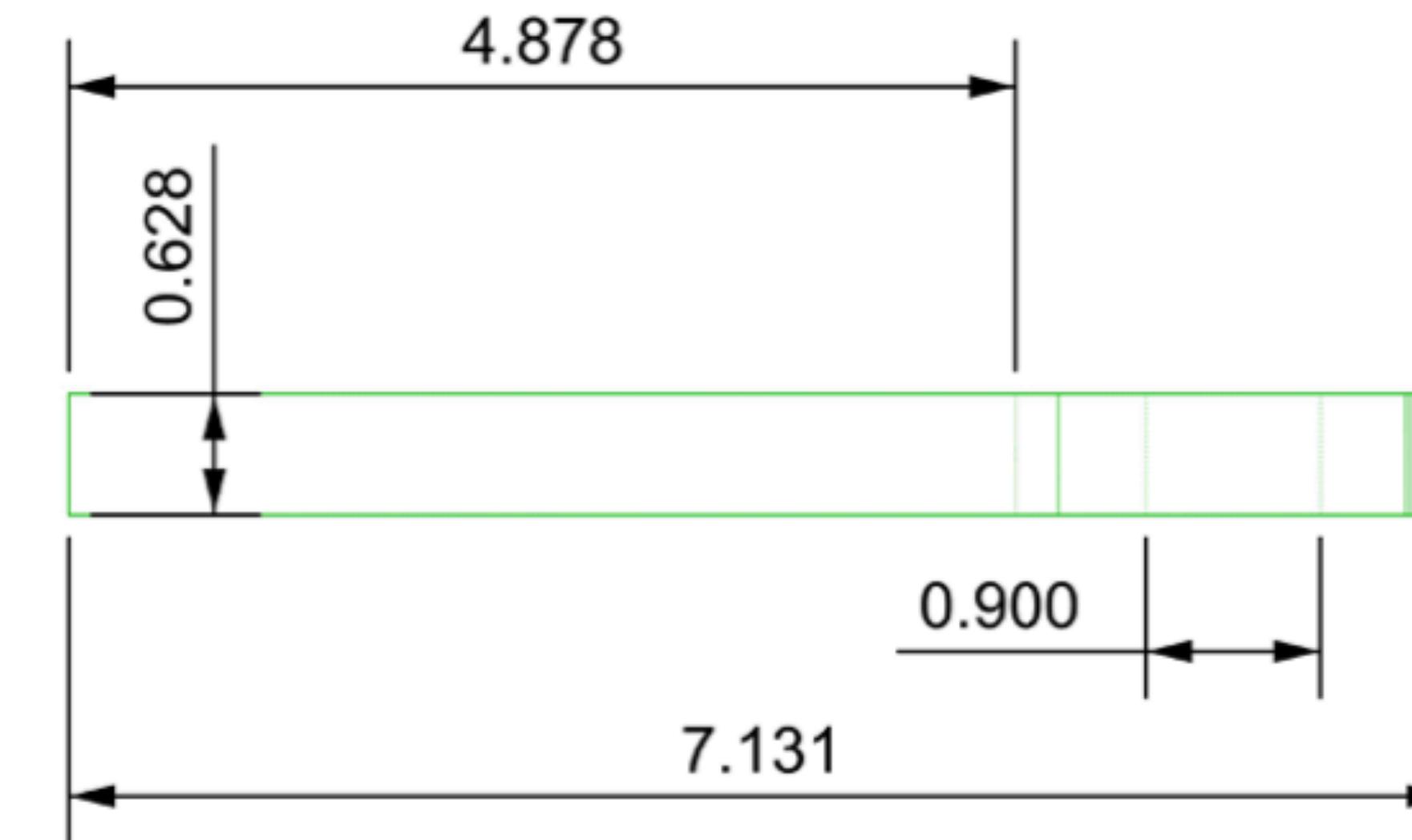
## **Manufacturing**

- Identify the best manufacturing method for making a Box Lewis assembly.
  - Dimension based on the sample assembly
  - Assembly must be functional
  - Assembly must look as close to the original as possible
  - Optimize cost as much as possible

# QUOTING REPRESENTATIVE PART

“Make” Parts representative only

- Selected “inside large” (see figure below) to get estimates.
- “Inside large” is a good representation of the rest of the parts that need to be manufactured. Not including the Clevis Assembly



# XOMETRY

## 3D Printed Quote - Aluminum

Xometry

Quote Q88-8443-9747 / Configure Part

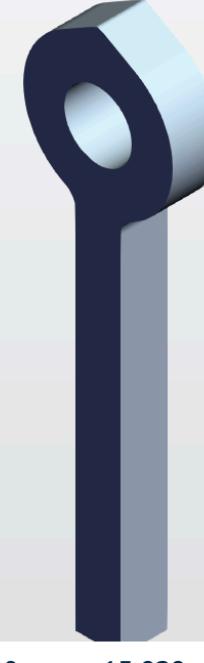
InsideBig.stl | V0 | Revise CAD | Upload Drawings

Inside Big - Aluminum(DMLS)

Standard | Made in USA  
**\$643.87** \$643.87 ea.  
\$799.02 (Save \$155.15)  
Free Shipping

Show Other Price Tier Options

Click to move model



181.334 mm x 50.800 mm x 15.939 mm | 7.139 in x 2.000 in x 0.628 in | 3.498 in<sup>3</sup>

Process: Metal 3D Printing

Technology: Direct Metal Laser Sintering (DMLS)

Material: Aluminum AlSiMg

Finish: Standard

Threads and Tapped Holes:  Threads and Tapped Holes i

Inserts:

Configure Analyze

Cancel Save Properties

Search

Search the menu for process, materials, ai

Feedback 

\$643.87

Material: AlSiMg  
Direct Metal Laser Sintering

Pending: Need to research material properties.

Notes: Continue if water jet or laser/plasma do not work

# XOMETRY

## 3D Printed Quote - Steel 17-4

Xometry

Quote Q88-8443-9747 / Configure Part

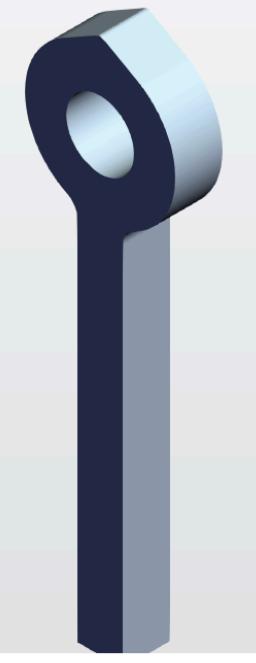
InsideBig.stl V0 Revise CAD Upload Drawings

Inside Big - 17-4 Steel (DMSL)

Standard | Made in USA  
**\$1,345.00** \$1,345.00 ea.  
\$1,669.10 (Save \$324.10)  
Free Shipping

Show Other Price Tier Options

Click to move model



181.334 mm x 50.800 mm x 15.939 mm | 7.139 in x 2.000 in x 0.628 in | 3.498 in<sup>3</sup>

Process: Metal 3D Printing

Technology: Direct Metal Laser Sintering (DMLS)

Material: Stainless 17-4

Finish: Standard

Threads and Tapped Holes:  Threads and Tapped Holes ⓘ

Configure Analyze

Cancel Save Properties

Search

Search the menu for process, materials, ai

Spec Sheet

Add

Inserts

\$1,345.00

Material: Steel 17-4  
Direct Metal Laser Sintering

Pending: Need to research material properties.

Notes: Continue if water jet or laser/plasma do not work

# XOMETRY

## 3D Printed Quote - Steel 316L

Xometry

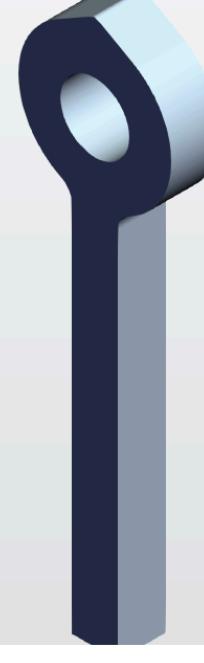
Quote Q88-8443-9747 / Configure Part

InsideBig.stl V0 Revise CAD Upload Drawings

Standard | Made in USA  
**\$1,345.00** \$1,345.00 ea.  
\$1,669.10 (Save \$324.10)  
Free Shipping

Show Other Price Tier Options

Click to move model



181.334 mm x 50.800 mm x 15.939 mm | 7.139 in x 2.000 in x 0.628 in | 3.498 in<sup>3</sup>

Process: Metal 3D Printing

Technology: Direct Metal Laser Sintering (DMLS)

Material: Stainless Steel 316L

Finish: Standard

Add

Threads and Tapped Holes

Threads and Tapped Holes i

Configure Analyze

Inside Big - Steel 316L (DMLS)

Cancel Save Properties

Search

Search the menu for process, materials, ai

\$1,345.00

Material: Steel 316L  
Direct Metal Laser Sintering

Pending: Need to research material properties.  
Notes: Continue if water jet or laser/plasma do not work

# PROTOLABS

## 3D Printed Quote - Multiple Metals

The screenshot shows a user profile for Santiago T. and a navigation menu with links to Projects, Parts, Order History, Design Guides, Contact Us, Give Us Feedback, Protolabs Companies, and Hubs | myRapid. The main content area displays a quote for "RCrough (Quote 1258-396)" with a "Pending" status and a note about research material properties. It lists several materials with their respective prices: AISiMg (\$1,037.66), Cobalt Chrome (\$1,866.02), Inconel 718 (\$2,006.53), Steel 17-4 (\$1,401.13), and Titanium (\$2,053.03). A blue box highlights the "inside\_big" text.

AISiMg	\$1,037.66
Cobalt Chrome	\$1,866.02
Inconel 718	\$2,006.53
Steel 17-4	\$1,401.13
Titanium	\$2,053.03

Material: see list  
Direct Metal Laser Sintering

Pending: Need to research material properties.  
Notes: Continue if water jet or laser/plasma do not work

### Materials and Resolutions

#### Direct Metal Laser Sintering (DMLS)

Aluminum AISi10Mg

High Res    Micro Res    Normal Res

Request    N/A    \$1,037.66

Cobalt Chrome

Request    N/A    \$1,866.02

Inconel 718

Request    N/A    \$2,006.53

Stainless Steel 17-4PH

Request    N/A    \$1,401.13

Stainless Steel 316L

Request    N/A    \$1,428.47

Titanium Ti-6Al-4V

Request    N/A    \$2,053.03

Protolabs Companies

Hubs | myRapid

Inconel 718 (X Line)

N/A    N/A    Request

Aluminum AISi10Mg (X Line)

N/A    N/A    Request

# SHAPEWAYS

## 3D Printed Quote - Aluminum

SHAPEWAYS



### Bring your product to life

InsideBig [TOOLS](#)

Aluminum (L-PBF) [CHANGE](#)

[Choose Options](#)

#### MATERIALS / FINISHES

##### Standard

Matte with a subtle sparkle and a slightly textured surface.



\$694.36

Material: AISiMg  
L-PBF

**Pending:** Need to research material properties.

**Notes:** Continue if water jet or laser/plasma do not work

# SHAPEWAYS

## 3D Printed Quote - Steel 420 / Bronze

SHAPEWAYS

The screenshot shows a 3D model of a keychain with a quote engraved on it. The model is shown from a slightly elevated angle. Below the model, there are coordinate values: X 2, Y 7.14, Z 0.63, and a 'RESIZE' button. To the right of these values is a 'IN ▾' dropdown menu.

**TOOLS**

InsideBig

**420i Steel/Bronze (BJT)[Steel]** CHANGE

**Choose Options**

**COLOR**

- Black
- Bronzed-Silver +\$0
- Bronze +\$86.12
- Gold Unavailable for this size
- Nickel Unavailable for this size

**MATERIALS / FINISHES**

- Matte This finish is unpolished for a rougher matte surface.
- Polished & Bronzed +\$18.15 Polishing provides a shiny, smooth look with a hint of bronze color.

**ADD TO CART** QTY 1 **\$373.13**

\$373.13

Material: 420 Steel/Bronze  
BJT

**Pending:** Need to research material properties.

**Notes:** Continue if water jet or laser/plasma do not work

# QUOTE SUMMARY

## 3D Printed Quote - Metal

	Xometry	Protolabs	Shapeways	Method	“Inside Large”	~ for X Parts
AISiMg	643.87	1,037.66	694.36	3DP		
Steel 17-4	1,345.00	1,401.13		3DP		
Steel 316L	1,345.00			3DP		
Cobalt Chrome		1,866.02		3DP		
Inconel 718		2,006.53		3DP		
Titanium		2,053.03		3DP		
Steel 420 / bronze			373.13	3DP		

# STATUS AND NEXT STEPS

5/9/2023

- Status:
  - Initial RFQs for 3D printed metal completed
    - Cost is high, ~ 1K per component.
    - Material properties need verification is used.
    - Unable to quote Waterjet or Laser cutting due to CAD file formats
      - STL files cannot be used for this mfg method.
- Next Steps:
  - Convert files into required formats for Waterjet or Laser cutting quotes
  - Continue research for COTS parts (clevis assembly)

✖ **Sheet Cutting is not available for mesh file formats.** Autoquoting Sheet Cutting (Laser/Waterjet) is not available for mesh file formats. To quote in Sheet Cutting (Laser/Waterjet), please provide a .step, .sldprt, .x\_b, .x\_t, .3dxml, .catpart, .prt, or .sat.

[Revise CAD](#)

**UPDATES 5/18**  
**UPDATES 7/16**

# QUOTE SUMMARY - SHEET CUTTING

## XOMETRY

	<b>0.250 THK</b>	<b>0.625 THK</b>	<b>1.000 THK</b>	<b>1.625 OR 1.745 THK</b>	<b>TOTAL</b>
ALUMINUM 6061 T6	68.93	83.12	98.25	N/A Custom quote	
ALUMINUM 7075 T6	70.44	86.65	103.92	N/A Custom quote	
STAINLESS STEEL 304	83.23	122.22	164.07	245.55	696.55
STAINLESS STEEL 316	89.84	138.76	190.51	474.90 or 245.55?	1,178.40 or 719.70
HOT ROLLED STEEL 1045	82.46	120.60	161.67	340.08	883.22
STEEL 1018	80.57	115.89	154.15	248.15	692.76
STEEL A36	78.51	110.70	145.81	240.11	669.43

# MATERIAL PROPERTIES

## SHEET CUTTING - (ENGLISH)

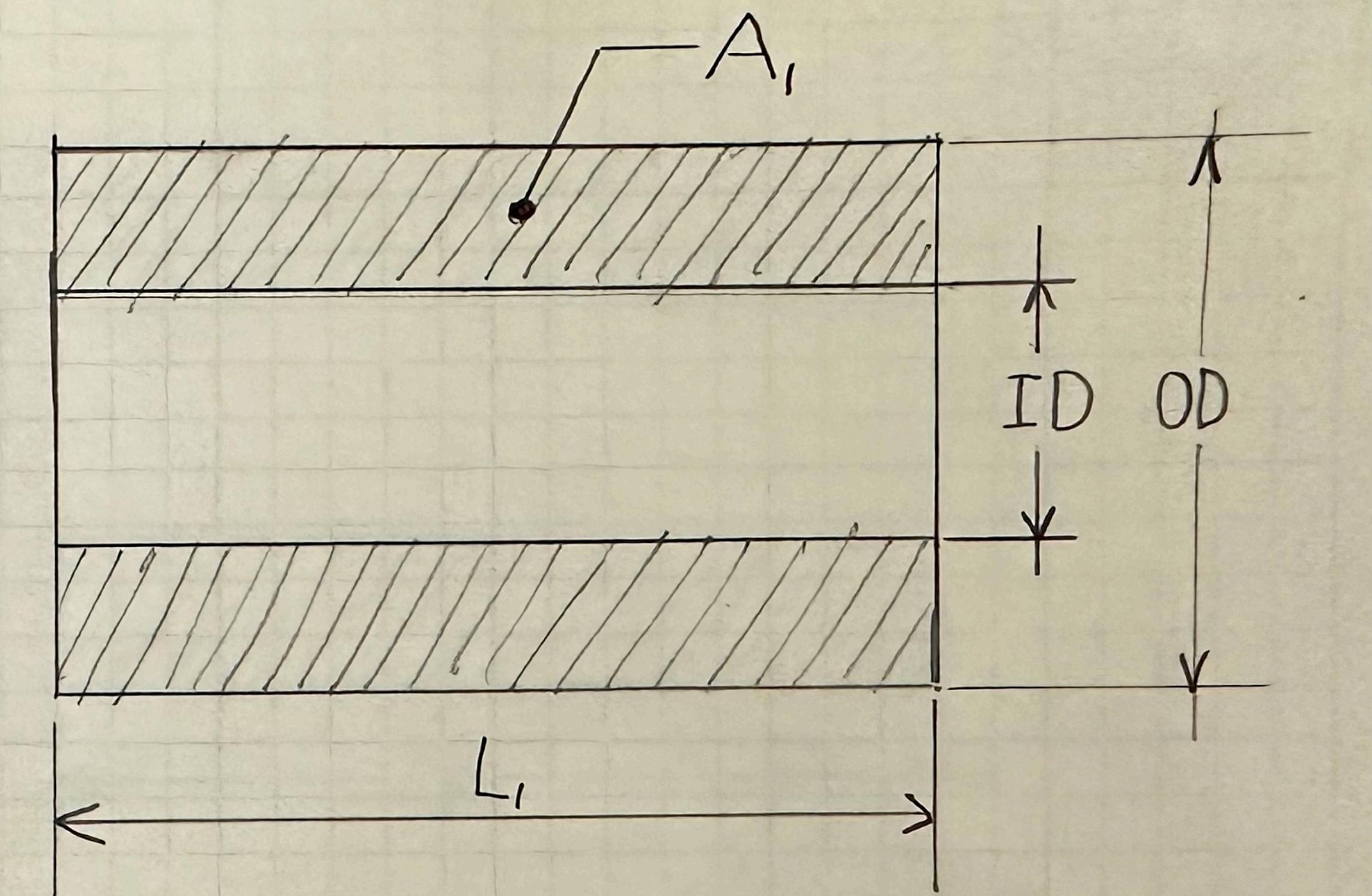
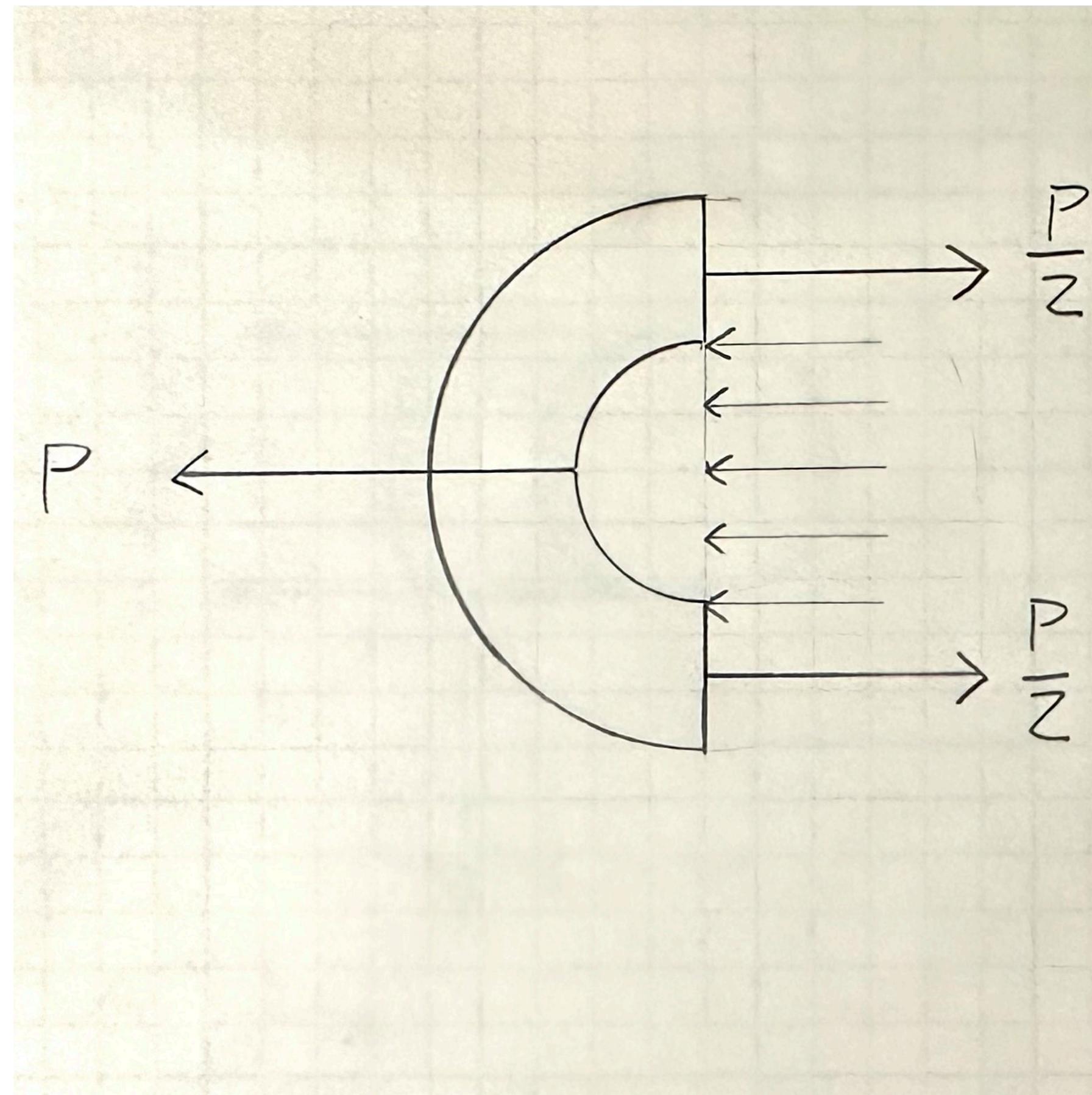
	TENSILE STRENGTH YIELD (psi)	TENSILE STRENGTH ULTIMATE (psi)	SHEAR MODULUS (ksi)	ELONGATION AT BREAK (%)	HARDNESS (Brinell)	DENSITY (lb/in^3)	APPROXIMATE COST - SHEET CUT OP (\$)
STAINLESS STEEL 304	31200	73200	11200	70	123	0.289	696.55
STAINLESS STEEL 316	42100	81200		50		0.289	TBD
HOT ROLLED STEEL 1045	65300	84800	11600	12	163	0.284	883.22
STEEL 1018	53700	63800	11300	15	126	0.284	692.76
STEEL A36	36300	58000	11500	20		0.282	669.43

# MATERIAL PROPERTIES

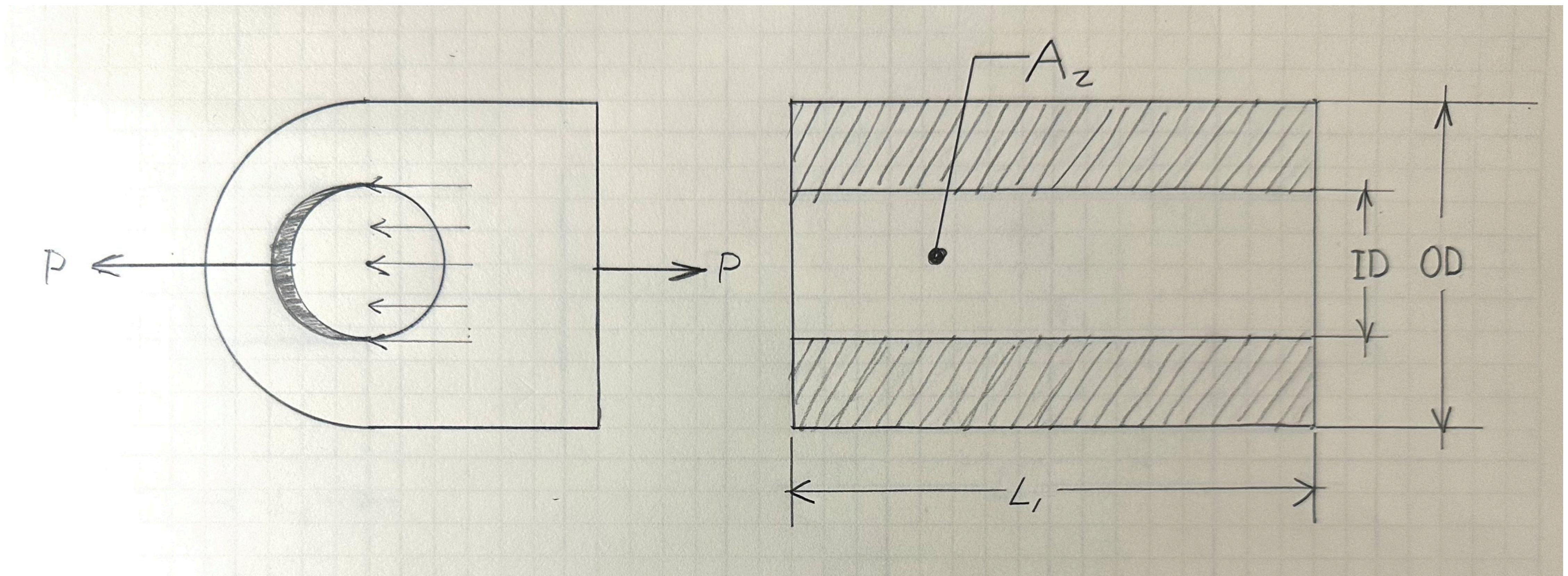
## SHEET CUTTING - (METRIC)

	TENSILE STRENGTH YIELD (MPa)	TENSILE STRENGTH ULTIMATE (MPa)	SHEAR MODULUS (GPa)	ELONGATION AT BREAK (%)	HARDNESS (Brinell)	DENSITY (g/cm^3)	APPROXIMATE COST - SHEET CUT OP (\$)
STAINLESS STEEL 304	215	505	77.0	70	123	8	696.55
STAINLESS STEEL 316	290	560		50		8	TBD
HOT ROLLED STEEL 1045	450	585	80	12	163	7.87	883.22
STEEL 1018	379	440	78	15	126	7.87	692.76
STEEL A36	250	400	79.3	20		7.8	669.43

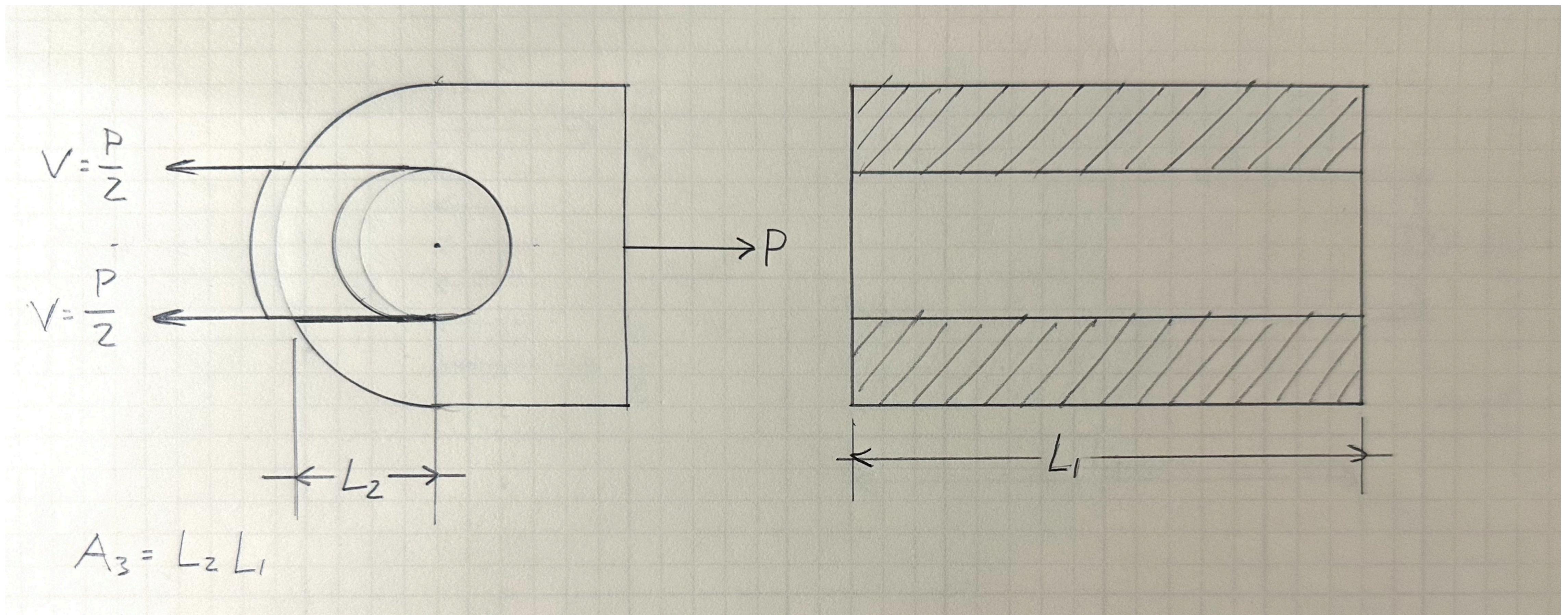
# Failure Mode 1 - Tension Keys



# Failure Mode 2 - Bearing Keys



# Failure Mode 3 - Shear Keys



# Back up

# 304 SST PROPERTIES

This grade of stainless steel has an austenitic crystal structure and is one of the most widely used grades. 304 is often conflated with 18-8 stainless steel but has slight differences in some of its alloying elements. It has good corrosion resistance characteristics and excellent formability, making it ideal for sheet metal components. Applications can include food processing equipment like tanks and structural bracketing.

## 304 Stainless Steel

Categories: [Metal](#); [Ferrous Metal](#); [Heat Resisting](#); [Stainless Steel](#); [T 300 Series Stainless Steel](#)

**Material Notes:** This MatWeb entry has typical values for specimens of unknown form/heat treatment but appear to be annealed samples. We are creating other entries for more specific heat treatments and forms. Austenitic Cr-Ni stainless steel. Better corrosion resistance than Type 302. High ductility, excellent drawing, forming, and spinning properties. Essentially non-magnetic, becomes slightly magnetic when cold worked. Low carbon content means less carbide precipitation in the heat-affected zone during welding and a lower susceptibility to intergranular corrosion.

**Applications:** beer kegs, bellows, chemical equipment, coal hopper linings, cooking equipment, cooling coils, cryogenic vessels, dairy equipment, evaporators, flatware utensils, feedwater tubing, flexible metal hose, food processing equipment, hospital surgical equipment, hypodermic needles, kitchen sinks, marine equipment and fasteners, nuclear vessels, oil well filter screens, refrigeration equipment, paper industry, pots and pans, pressure vessels, sanitary fittings, valves, shipping drums, spinning, still tubes, textile dyeing equipment, tubing.

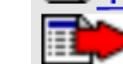
**Corrosion Resistance:** resists most oxidizing acids and salt spray.

UNS S30400; AMS 5501, 5513, 5560, 5565; ASME SA182, SA194 (8), SA213, SA240; ASTM A167, A182, A193, A194

**Key Words:** aisi304, AISI 304, T304, SUS304, SS304, 304SS, 304 SS, UNS S30400, AMS 5501, AMS 5513, AMS 5560, AMS 5565, AMS 5566, AMS 5567, AMS 5639, AMS 5697, ASME SA182, ASME SA194 (8), ASME SA213, ASME SA240, ASME SA249, ASME SA312, ASME SA320 (B8), ASME SA358, ASME SA376, ASME SA403, ASME SA409, ASME SA430, ASME SA479, ASME SA688, ASTM A167, ASTM A182, ASTM A193, ASTM A194, ASTM A666, FED QQ-S-763, MILSPEC MIL-S-5059, SAE 30304, DIN 1.4301, X5CrNi189, B.S. 304 S 15, EN 58E, PN 86020 (Poland), OH18N9, ISO 4954 X5CrNi189E, ISO 683/13 11, 18-8

**Vendors:** [Click here to view all available suppliers for this material.](#)

Please [click here](#) if you are a supplier and would like information on how to add your listing to this material.

 [Printer friendly version](#)  [Download as PDF](#)  [Download to Excel \(requires Excel and Windows\)](#)  
 [Export data to your CAD/FEA program](#)

Add to Folder:  My Folder 0/0

Physical Properties	Metric	English	Comments
Density	8.00 g/cc	0.289 lb/in <sup>3</sup>	
Mechanical Properties	Metric	English	Comments
Hardness, Brinell	123	123	Converted from Rockwell B hardness.
Hardness, Knoop	138	138	Converted from Rockwell B hardness.
Hardness, Rockwell B	70	70	
Hardness, Vickers	129	129	Converted from Rockwell B hardness.
Tensile Strength, Ultimate	505 MPa	73200 psi	
Tensile Strength, Yield	215 MPa @Strain 0.200 %	31200 psi @Strain 0.200 %	
Elongation at Break	70 %	70 %	in 50 mm
Modulus of Elasticity	193 GPa	28000 ksi	
Poissons Ratio	0.29	0.29	
Shear Modulus	77.0 GPa	11200 ksi	



# 316 SST PROPERTIES

This austenitic grade of stainless steel contains molybdenum which further improves its resistance to corrosion. In addition to this, it is highly formable and weldable. Common applications include parts that are exposed to corrosive conditions like chemical tanks or marine equipment.

## AISI Type 316L Stainless Steel, annealed sheet

Categories: [Metal](#); [Ferrous Metal](#); [Stainless Steel](#); [T 300 Series Stainless Steel](#)

**Material Notes:** Similar to Type 316 for superior corrosion resistance, but also has superior resistance to intergranular corrosion following welding or stress relieving. Good corrosion resistance to most chemicals, salts, and acids and molybdenum content helps resistance to marine environments. The low carbon content of 316L reduces the possibility of in vivo corrosion for medical implant use. High creep strength at elevated temperatures. 316L has fabrication characteristics similar to Types 302 and 304.

**Applications:** biomedical implants, chemical processing, food processing, photographic, pharmaceutical, textile finishing, marine exterior trim.

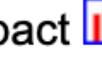
**Key Words:** UNS S31603, AISI 316L, ISO 2604-1 F59, ISO 2604-4 P57, ISO 2604-4 P58, ISO 4954 X2CrNiMo17133E, ISO 683/13 19, ISO 683/13 19a, biomaterials, biomedical implants, biocompatible materials

**Vendors:** No vendors are listed for this material. Please [click here](#) if you are a supplier and would like information on how to add your listing to this material.

 [Printer friendly version](#)  [Download as PDF](#)  [Download to Excel \(requires Excel and Windows\)](#)  
 [Export data to your CAD/FEA program](#)

Add to Folder:  My Folder  0/0

Physical Properties	Metric	English	Comments
Density	8.00 g/cc	0.289 lb/in <sup>3</sup>	

Mechanical Properties	Metric	English	Comments
Hardness, Rockwell B	79	79	
Tensile Strength, Ultimate	560 MPa	81200 psi	
Tensile Strength, Yield	290 MPa	42100 psi	
Elongation at Break	50 %	50 %	in 50 mm
Tensile Modulus	193 GPa	28000 ksi	
Izod Impact 	150 J @Temperature -195 °C	111 ft-lb @Temperature -319 °F	
	150 J @Temperature 21.0 °C	111 ft-lb @Temperature 69.8 °F	
Charpy Impact	103 J	76.0 ft-lb	V-notch, 30°C

Electrical Properties	Metric	English	Comments
Electrical Resistivity	0.0000740 ohm-cm	0.0000740 ohm-cm	at 20°C
Magnetic Permeability	1.008	1.008	at RT

Thermal Properties	Metric	English	Comments
Specific Heat Capacity	0.500 J/g-°C @Temperature 0.000 - 100 °C	0.120 BTU/lb-°F @Temperature 32.0 - 212 °F	
Thermal Conductivity	14.0 - 15.9 W/m-K	97.0 - 110 BTU-in/hr-ft <sup>2</sup> -°F	
Melting Point	1375 - 1400 °C	2507 - 2550 °F	
Solidus	1375 °C	2507 °F	
Liquidus	1400 °C	2550 °F	



# 1045 STEEL PROPERTIES

There are numerous uses for 1045 carbon steel in different industries. It is suitable for manufacturing a variety of components due to its high tensile strength and good machinability. Gears, bolts, studs, axles, crankshafts, and machinery parts are a few examples of common applications for 1045 steel. Furthermore, it is used in products like hydraulic shafts, couplings, and farm machinery that need to be strong and impact resistant. 1045 carbon steel strikes a favorable balance between affordability and impressive properties such as strength, machinability, and wear resistance. This makes it a preferred choice for various applications, including blades, cutting tools, and industrial knives that are exposed to wear and abrasion. 1045 carbon steel's versatility and reliable performance make it highly sought-after in the manufacturing and engineering industries.

## AISI 1045 Steel, cold drawn, high temperature stress relieved, 50-75 mm (2-3 in) round

Categories: [Metal](#); [Ferrous Metal](#); [Carbon Steel](#); [AISI 1000 Series Steel](#); [Medium Carbon Steel](#)

<b>Material Notes:</b>	Respond to heat treatment, and flame and induction hardening, but not recommended for carburizing or cyaniding. Die forging and hot upsetting are good to excellent. Typical uses include gears, shafts, axles, bolts, studs, and machine parts. AISI cross reference for JIS S45C and KS SM45C.
<b>Key Words:</b>	AFNOR NF A35-553 XC45, AFNOR NF A35-554 XC48, DIN 1654 1.1192, DIN 1654 Cq45, DIN 17200 1.0503, AFNOR XC42, AFNOR XC42TS, AFNOR XC48TS, AFNOR NF A33-101 AF65C45, AFNOR NF A35-552 XC48H1, UNS G10450, ASTM A29, ASTM A108, ASTM A266 Class 3, ASTM A304, ASTM A311, ASTM A510, ASTM A519, AS 1442 K1045 (Australia), AS 1442 S1045, AS 1443 K1045, AS 1443 S1045, AS 1446 K1045, AS 1446 S1045, ASTM A568, ASTM A576, ASTM A682, ASTM A827, ASTM A830, FED QQ-S-635, FED QQ-S-700, FED QQ-W-461, MIL S-24093, MIL S-3039, BDS 6354 45G2A, BDS 6354 45G2K2, BDS 6354 45G2K3, GB 3078 45 (China), GB 3088 45, GB 699 45, YB 6 45B, DIN 17200 1.1191, DIN 17200 1.1201, DIN 17200 C45, DIN 17200 CK45, DIN 17200 Cm45, DIN 17200 GS-CK45, DIN 17212 1.1193, FED QQ-S-635 (C1045), FED QQ-S-700 (C1045), SAE J403, SAE J412, SAE J414, DIN 1.1191, JIS S 48 C, SS14 1672 (Sweden), MIL S-46070, SAE J1397, SAE J403, SAE J412, BS 970 Part 1 O60A47 (U.K), BS 970 Part 1 080A47, BS 970 Part 1 080M46, NBN 253-02 C45-3, NBN 253-06 C46, BDS 3492 45LI (Bulgaria), BDS 3492 45LII, BDS 3492 45LIII, BDS 5785 45, BDS 6354 45G2, ONORM M3108 C45SW (Austria), ONORM M3110 RC45, ONORM M3161 C45, NBN 253-02 C45-1 (Belgium), NBN 253-02 C45-2
<b>Vendors:</b>	No vendors are listed for this material. Please <a href="#">click here</a> if you are a supplier and would like information on how to add your listing to this material.

Physical Properties	Metric	English	Comments
Density	7.87 g/cc	0.284 lb/in <sup>3</sup>	Typical for steel.

Mechanical Properties	Metric	English	Comments
Hardness, Brinell	163	163	
Hardness, Knoop	184	184	Converted from Brinell
Hardness, Rockwell B	84	84	Converted from Brinell
Hardness, Vickers	170	170	Converted from Brinell
Tensile Strength, Ultimate	585 MPa	84800 psi	
Tensile Strength, Yield	450 MPa	65300 psi	
Elongation at Break	12 %	12 %	in 50 mm
Reduction of Area	35 %	35 %	
Modulus of Elasticity	206 GPa	29900 ksi	
Bulk Modulus	163 GPa	23600 ksi	Estimated from elastic modulus
Poissons Ratio	0.29	0.29	Typical for steel
Shear Modulus	80.0 GPa	11600 ksi	Estimated from elastic modulus

Electrical Properties	Metric	English	Comments
Electrical Resistivity 	0.0000162 ohm-cm @Temperature 0.000 °C	0.0000162 ohm-cm @Temperature 32.0 °F	annealed specimen
	0.0000223 ohm-cm @Temperature 100 °C	0.0000223 ohm-cm @Temperature 212 °F	annealed specimen

# 1018 STEEL PROPERTIES

SAE / AISI 1018 is commonly used in applications such as gears, axles, shafts, pistons, pins, fasteners, bolts, springs, sprockets and crankshafts for automotive engines due to its high tensile strength and good formability properties. It is also used in furniture frames and components due to its good machinability properties, which allow it to be easily shaped into desired forms. Additionally, it is often used in food production due to its corrosion resistance qualities, making it a safe material for use in food processing equipment or machinery parts that come into contact with food items or liquids during production processes.

## AISI 1018 Steel, cold drawn

Categories: [Metal](#); [Ferrous Metal](#); [Carbon Steel](#); [AISI 1000 Series Steel](#); [Low Carbon Steel](#)

<b>Material Notes:</b>	Medium low-carbon steel, has good weldability and slightly better machinability than the lower carbon steels.
<b>Key Words:</b>	carbon steels, AMS 5069, ASTM A108, UNS G10180, AS 1442 K1018 (Australia), AS 1443 K1018, CSN 12020 (Czech), CSN 12022, AFNOR NF A33-101 AF42C20, DIN 1.0453, DIN C16.8, DGN B-301 1018 (Mexico), COPANT 331 1018 (Pan America), COPANT 333 1018, MST.T (Russia), ST.20A, ST.3, ST.3T, GOST M18S, GOST 23570 18ps, GOST 23570 18sp, GOST 5520 18K, GOST 5521 S, NBN 629 D37-2 (Belgium), NBN 630 E37-1, NBN 630 E37-2, NBN A21-221 C17KD, BDS 9801 S (Bulgaria), GB 715 ML3 (China), TS 302 Fe35.2 (Turkey), TS 346 Fe35, BS 970 080A17, DEF STAN95-1-1 C1018
<b>Vendors:</b>	No vendors are listed for this material. Please <a href="#">click here</a> if you are a supplier and would like information on how to add your listing to this material.

Physical Properties	Metric	English	Comments
Density	7.87 g/cc	0.284 lb/in <sup>3</sup>	

Mechanical Properties	Metric	English	Comments
Hardness, Brinell	126	126	
Hardness, Knoop	145	145	Converted from Brinell
Hardness, Rockwell B	71	71	Converted from Brinell
Hardness, Vickers	131	131	Converted from Brinell
Tensile Strength, Ultimate	440 MPa	63800 psi	
Tensile Strength, Yield	370 MPa	53700 psi	
Elongation at Break	15 %	15 %	In 50 mm
Reduction of Area	40 %	40 %	
Modulus of Elasticity	200 GPa	29000 ksi	
Bulk Modulus	159 GPa	23100 ksi	Estimated from elastic modulus
Poissons Ratio	0.29	0.29	Typical for steel
Machinability	70 %	70 %	Based on AISI 1212 steel = 100%
Shear Modulus	78.0 GPa	11300 ksi	Estimated from elastic modulus

Electrical Properties	Metric	English	Comments
Electrical Resistivity 	0.0000159 ohm-cm @Temperature 0.000 °C 0.0000219 ohm-cm @Temperature 100 °C 0.0000293 ohm-cm @Temperature 200 °C	0.0000159 ohm-cm @Temperature 32.0 °F 0.0000219 ohm-cm @Temperature 212 °F 0.0000293 ohm-cm @Temperature 392 °F	annealed condition annealed condition annealed condition

Thermal Properties	Metric	English	Comments
Specific Heat Capacity	0.486 J/g-°C @Temperature >=100 °C	0.116 BTU/lb-°F @Temperature >=212 °F	annealed
Thermal Conductivity	51.9 W/m-K	360 BTU-in/hr-ft <sup>2</sup> -°F	estimated based on similar materials

# A36 STEEL PROPERTIES

A36 steel is a steel composition formulated by ASTM (American Society for Testing and Materials). It is mild steel, also known as low-carbon steel, with a carbon content of 0.25%–0.3%. A36 steel also has roughly 1% manganese. This chemical composition gives A36 steel a well-rounded set of properties with good strength, weldability, and malleability at a low cost. For this reason, A36 steel is widely found in structural applications in the construction, automotive, and oil & gas industries.

A36 carbon steel was developed by ASTM International and is one of the most used carbon steels for structural applications. A36 steel exhibits excellent welding properties and is well-suited for punching, grinding, drilling, tapping, and machining. The properties of A36 make this steel suitable for a wide scope of applications when compared to other high-performing alloys. A36 steel is a paramagnetic material which means it is a good conductor of magnetic fields, therefore A36 steel is fairly opaque to electromagnetism.

## ASTM A36 Steel, plate

Categories: [Metal](#); [Ferrous Metal](#); [ASTM Steel](#); [Carbon Steel](#); [Low Carbon Steel](#)

**Material** Steel for general structural purposes including bridges and buildings.

**Notes:** Minimum Cu content when copper steel is specified.

Tests performed in transverse direction for plates wider than 590 mm.

**Key Words:** UNS K02600

**Vendors:** No vendors are listed for this material. Please [click here](#) if you are a supplier and would like information on how to add your listing to this material.

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Physical Properties	Metric	English	Comments
Density	7.80 g/cc	0.282 lb/in <sup>3</sup>	Typical of ASTM Steel

Mechanical Properties	Metric	English	Comments
Tensile Strength, Ultimate	400 - 550 MPa	58000 - 79800 psi	
Tensile Strength, Yield	250 MPa	36300 psi	
Elongation at Break	20 %	20 %	in 200 mm
	23 %	23 %	In 50 mm.
Modulus of Elasticity	200 GPa	29000 ksi	
Bulk Modulus	160 GPa	23200 ksi	Typical for steel
Poissons Ratio	0.26	0.26	
Shear Modulus	79.3 GPa	11500 ksi	

Component Elements Properties	Metric	English	Comments
Carbon, C	0.25 - 0.29 %	0.25 - 0.29 %	
Copper, Cu	0.20 %	0.20 %	
Iron, Fe	98 %	98 %	
Manganese, Mn	1.03 %	1.03 %	
Phosphorus, P	<= 0.040 %	<= 0.040 %	
Silicon, Si	0.28 %	0.28 %	
Sulfur, S	<= 0.050 %	<= 0.050 %	

# REFERENCE DOCUMENTS

## Documents in GitHub repo

- Shapeways All Materials-Guide-2021.pdf
- Shapeways-Aluminum\_General\_Info.pdf
- Shapeways-Steel\_General\_Info.pdf
- Protolabs Aluminum Datasheet - Material-Data-SheetAluminum.pdf
- Xometry - Stainless Steel 3D Printing | Material Properties and Applications.pdf