A Brief Introduction to Engineering Graphics

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Opening comments

- Engineering graphics is the method for documenting a design
- Mechanical engineering students must be familiar with standards of engineering graphics as it is expected in industry
- This set of slides introduces some of the basics, but is not comprehensive
- For more, see
  - Engineering Graphics section on the Resources page of the course ME2011 website
  - Any engineering graphics textbook

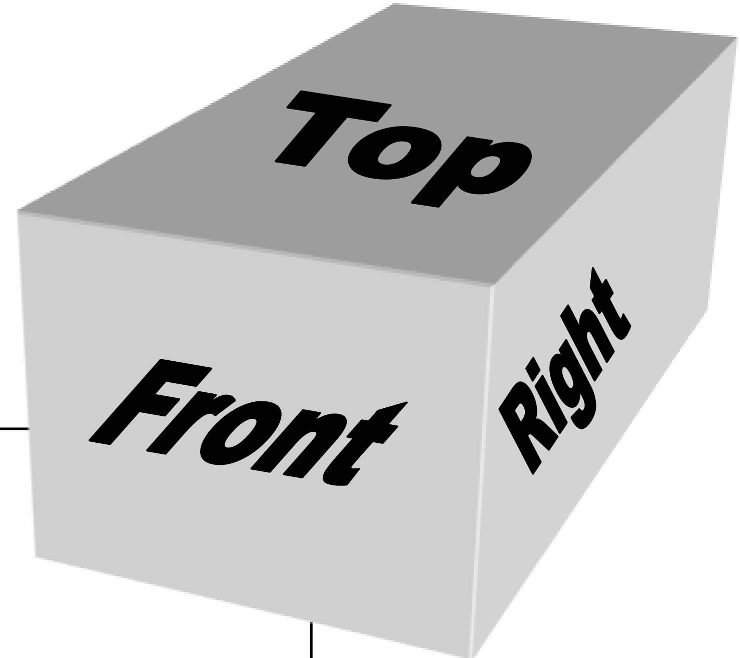
Documenting a part requires...

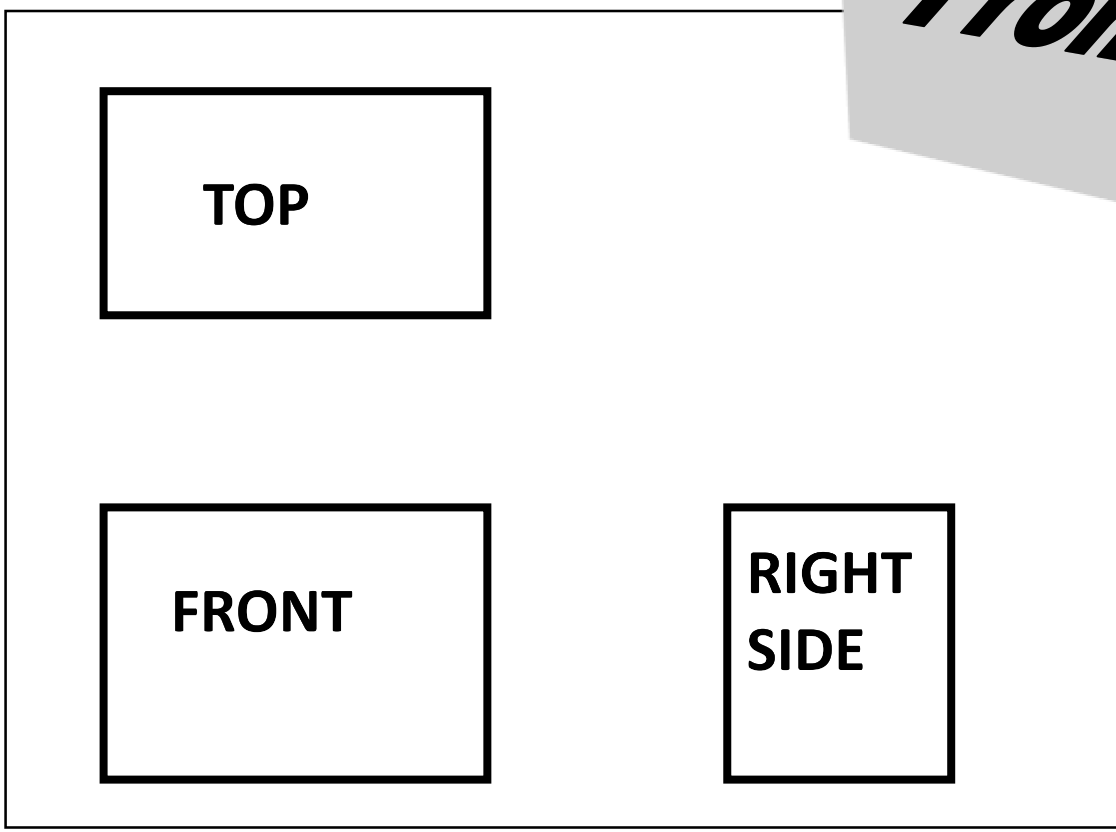
1. **SHAPE**
2. **SIZE**
3. **MATERIAL**
4. **TOLERANCE**
5. **FINISH**

Engineering drawings

- Universal language
- Conventions (drawing grammar) simplify communication; your drawing is at risk if you defy
- CAD packages make formal drawing easy…if you follow the conventions
- The machinist will laugh at you behind your back if you show up with a non-standard drawing

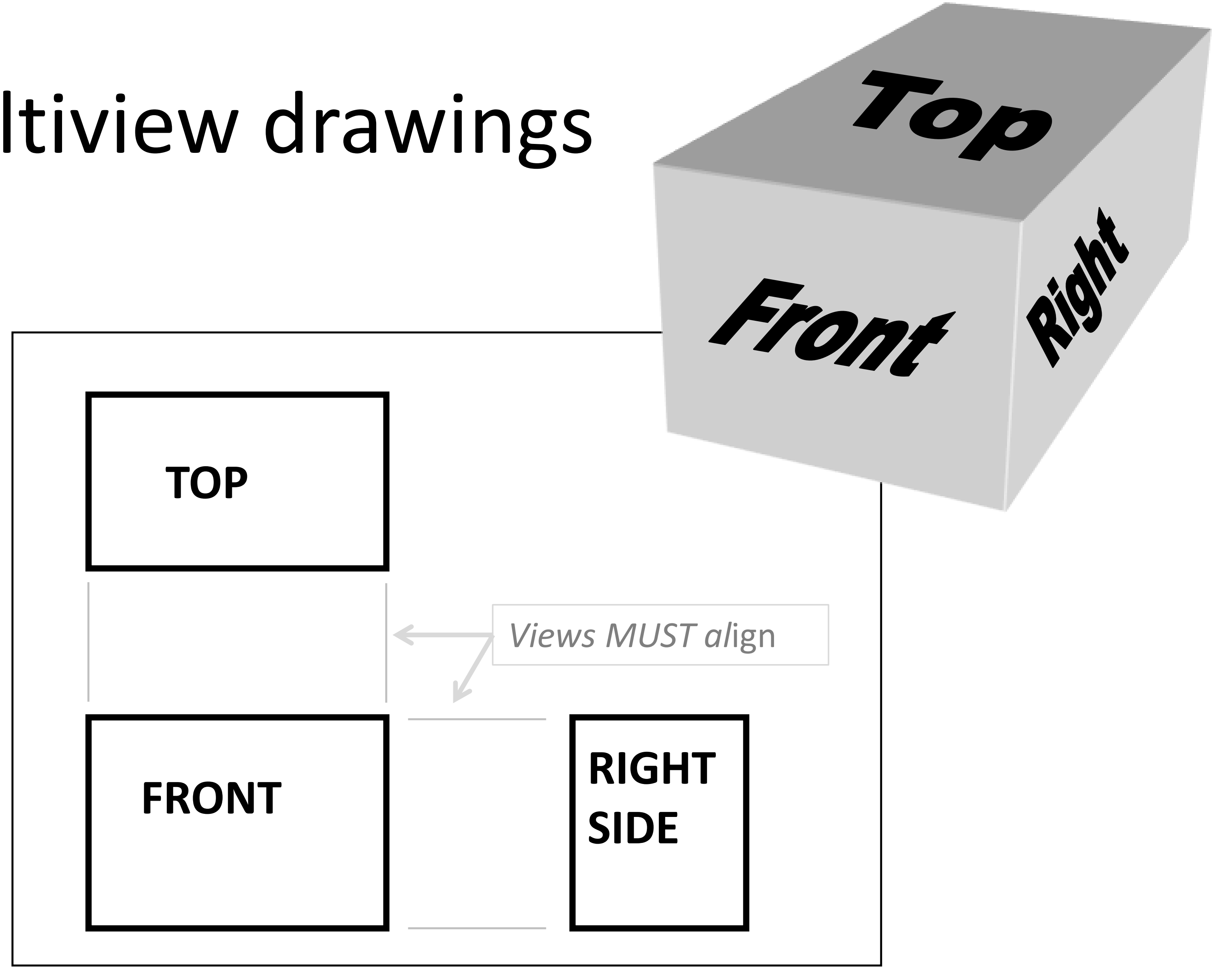
Multiview drawings





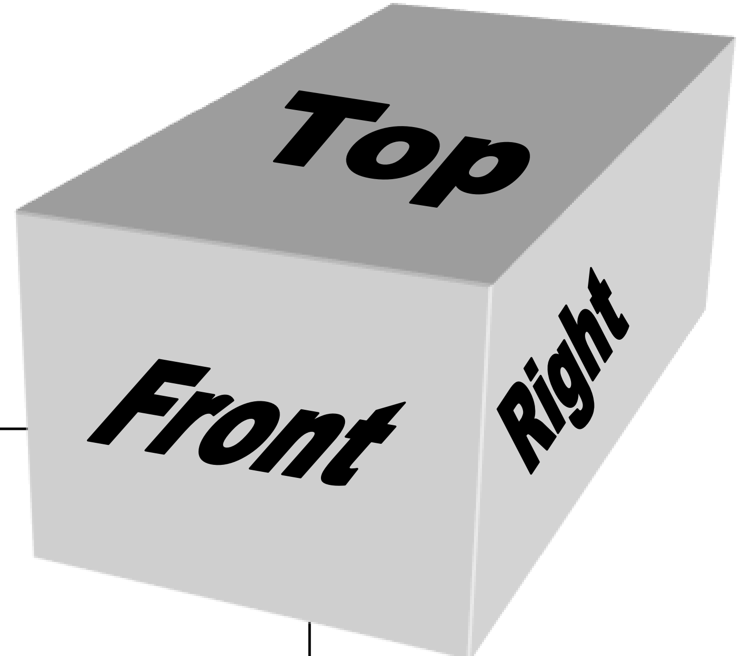
“3rd angle projection”

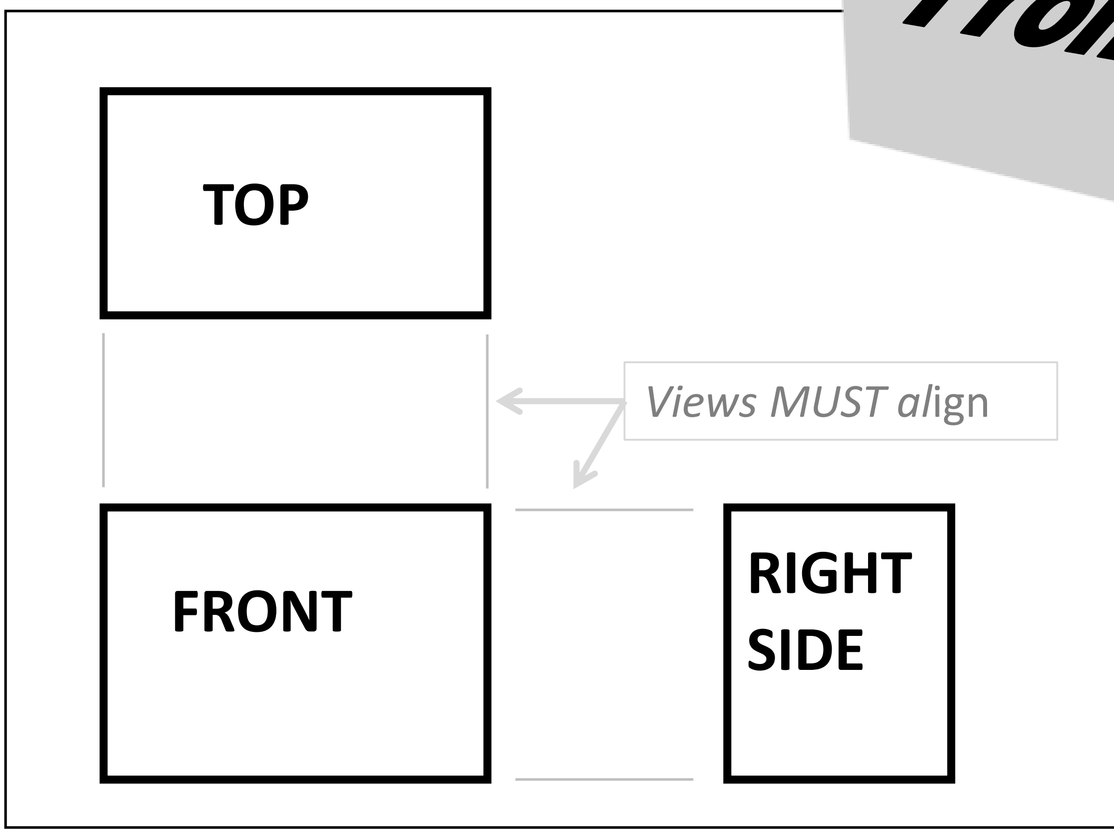
Multiview drawings



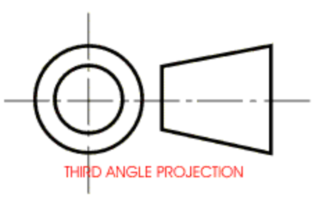
“3rd angle projection”

Multiview drawings

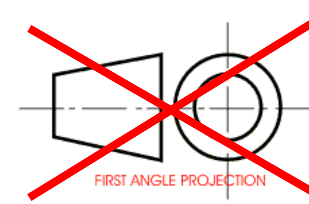




“3rd angle projection”

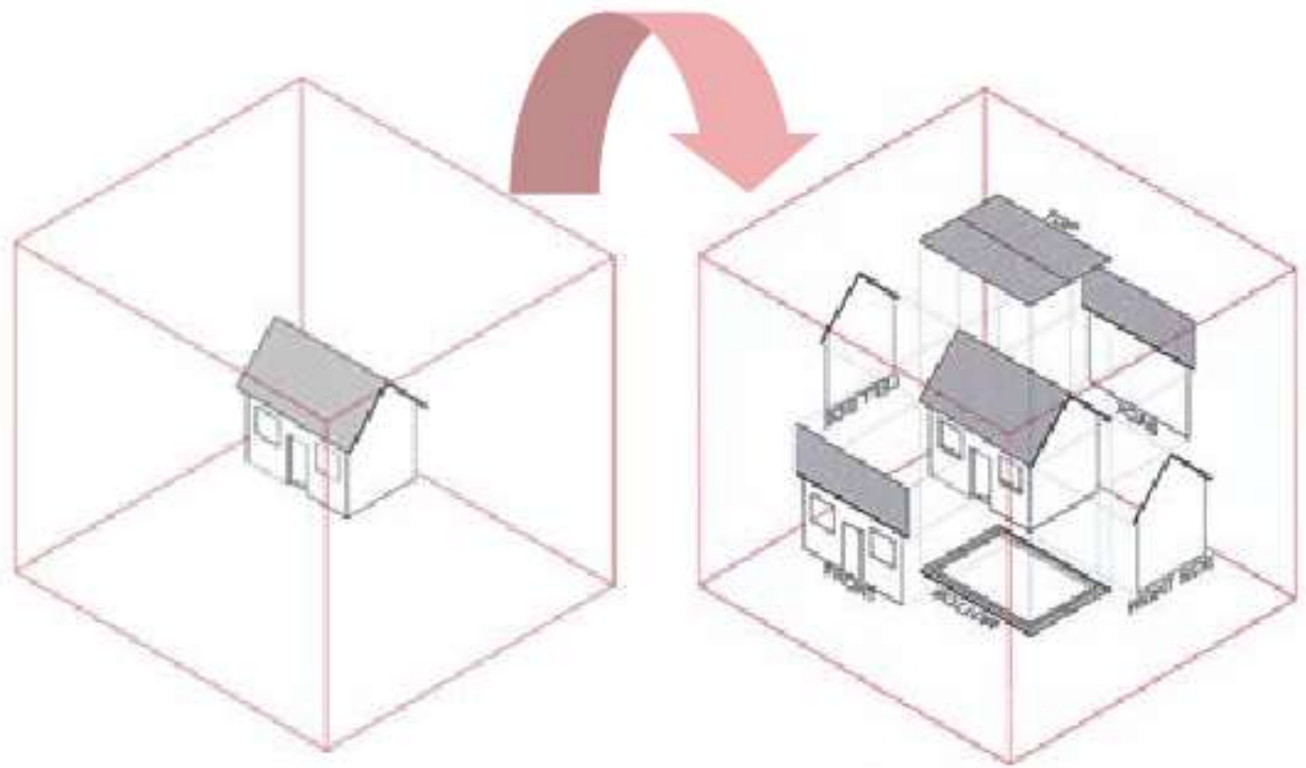


You walk around part to the right (US)



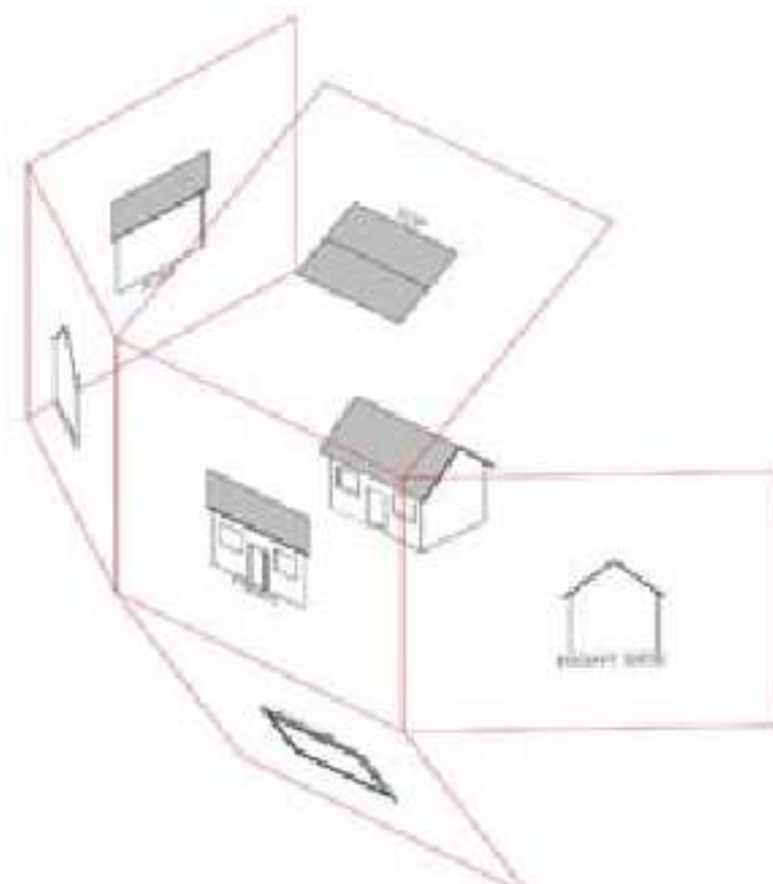
Rotate the part to the right (Europe)

The Glass Box:



Bertoline, Engineering Graphics

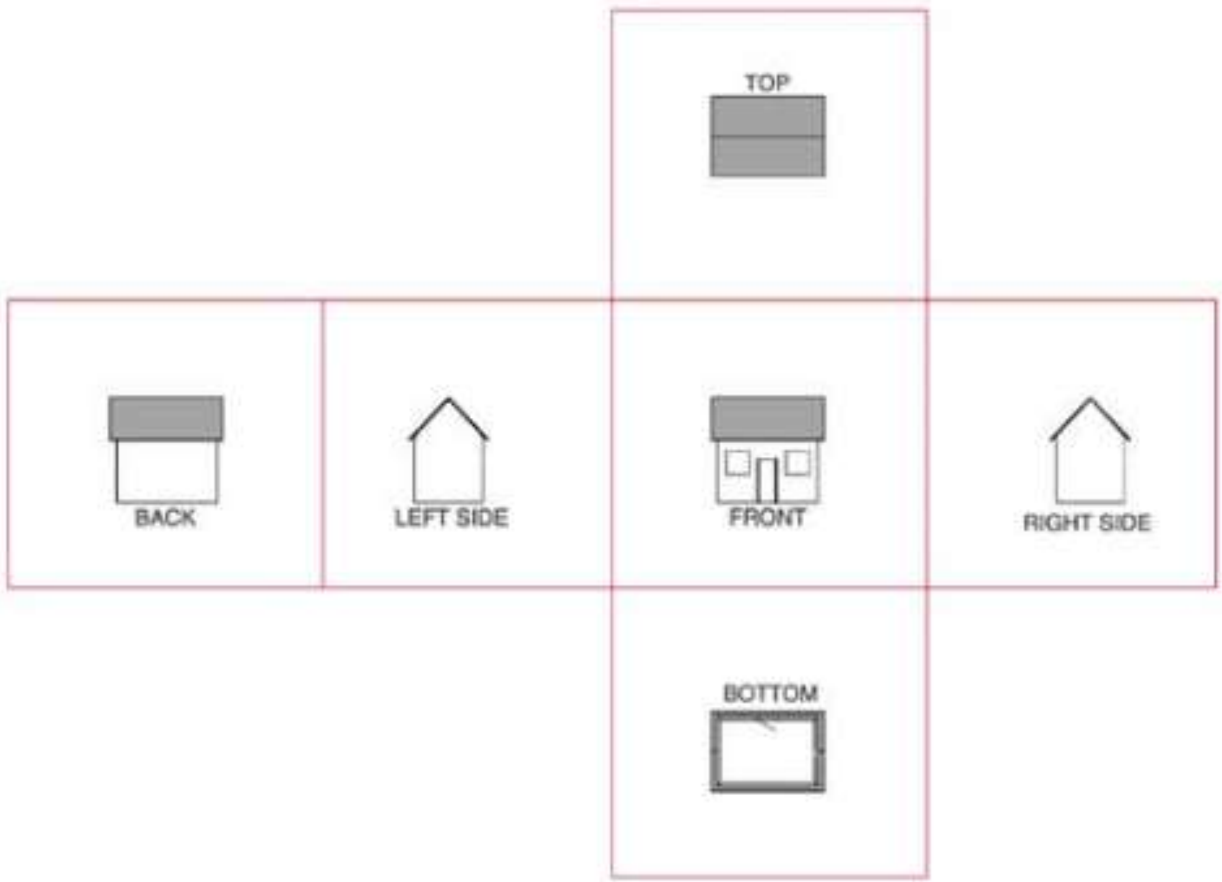
Alignment & Orientation are preserved…



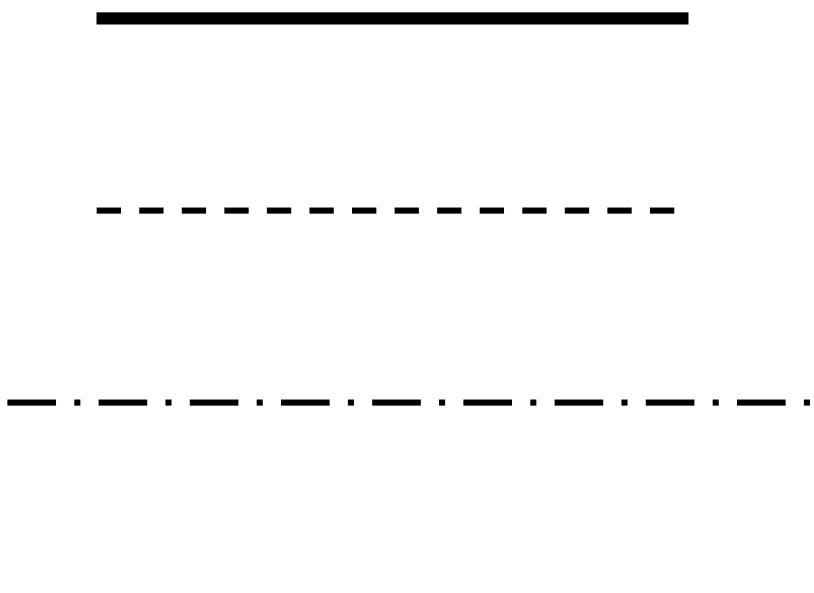
Unfolding the
"Glass Box"

Bertoline, Engineering Graphics

Six Principle views: obey layout



Basic lines (the “alphabet of lines”)



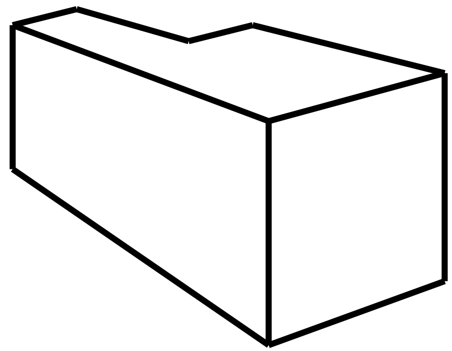
Object line

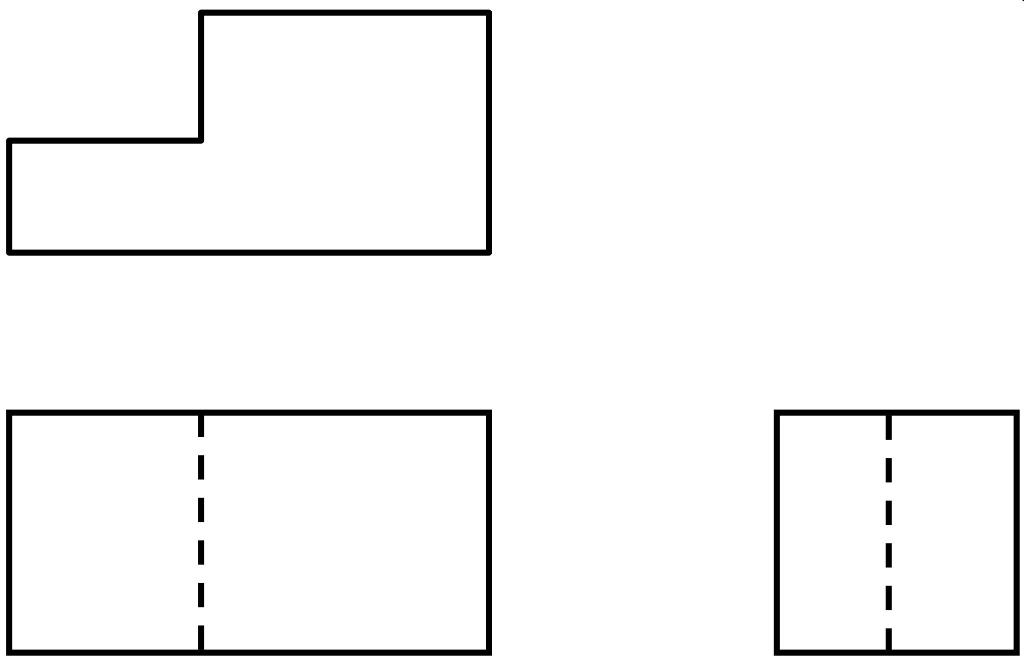
Hidden line

Center line

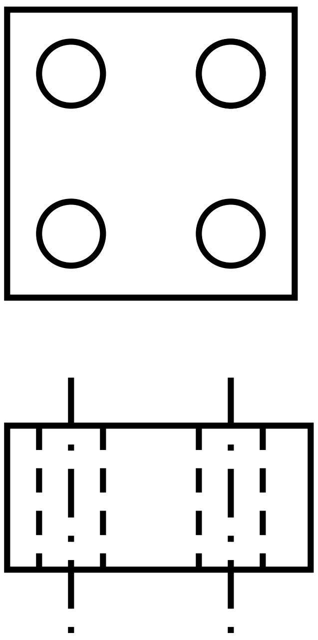
Dimension line

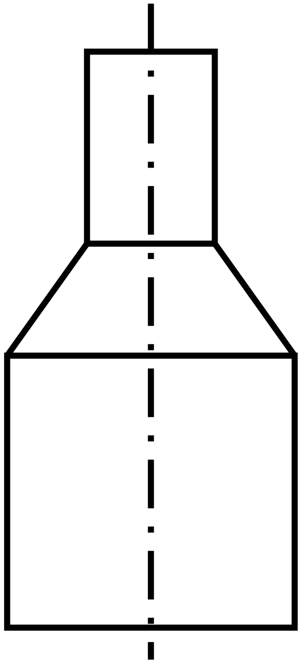
HIDDEN LINES



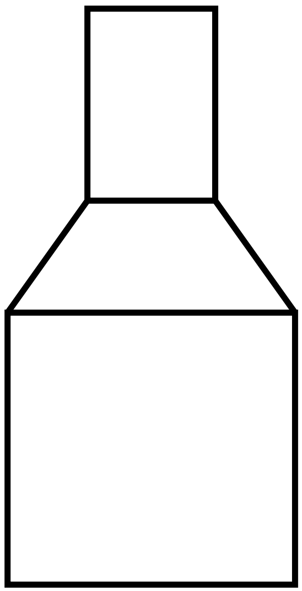


CENTER LINES

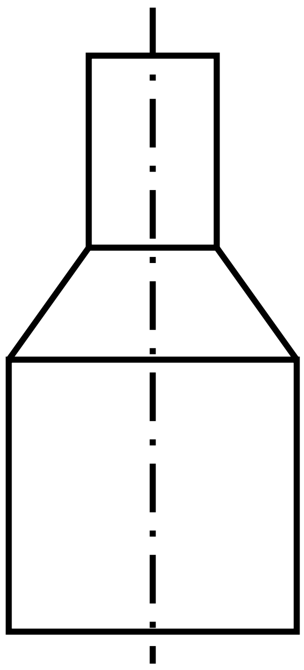




Interpreting Center Lines

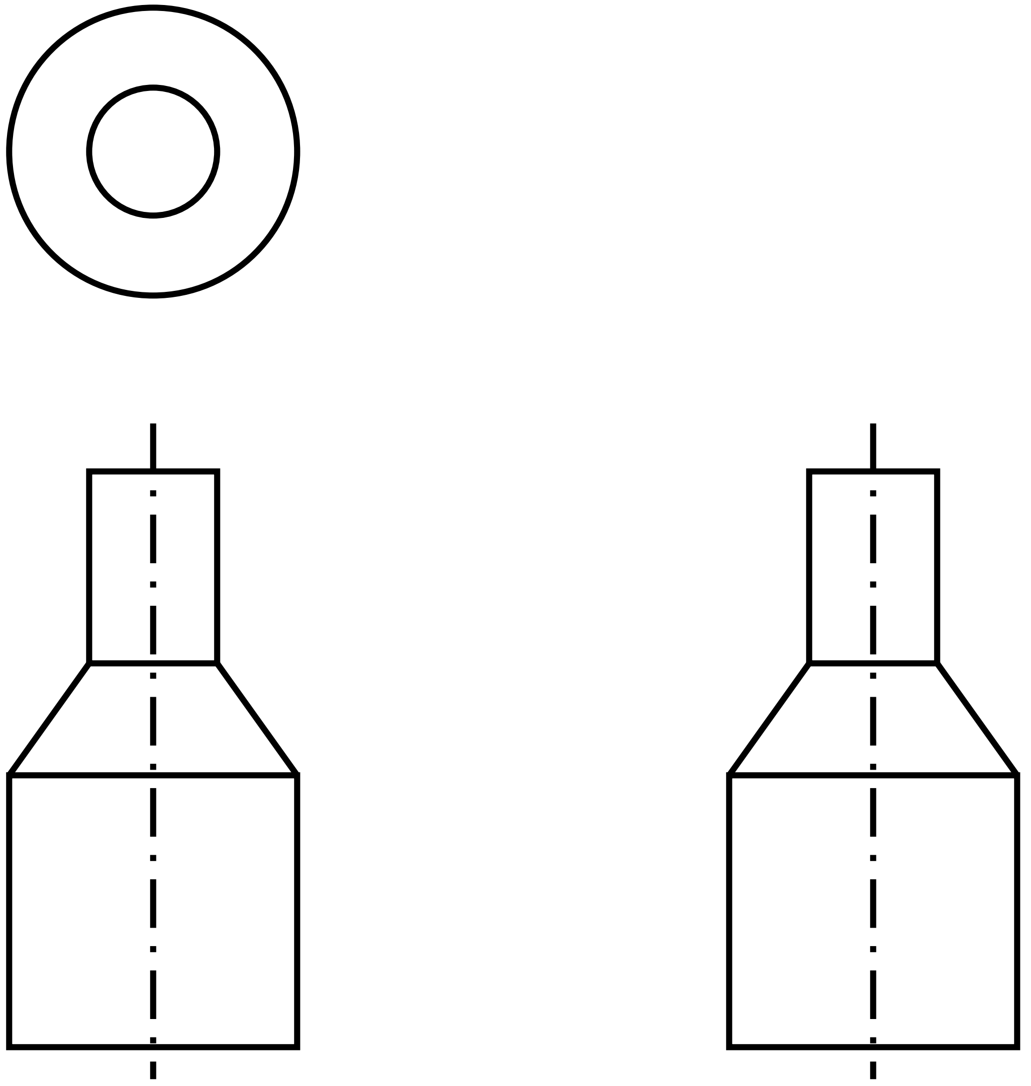


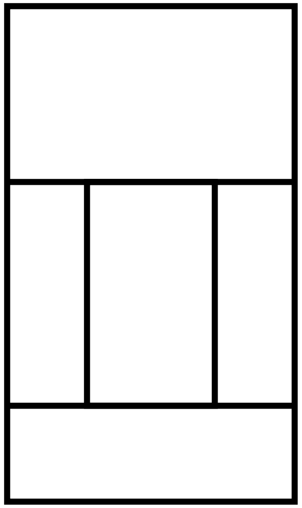
Enough Info?



Enough Info?

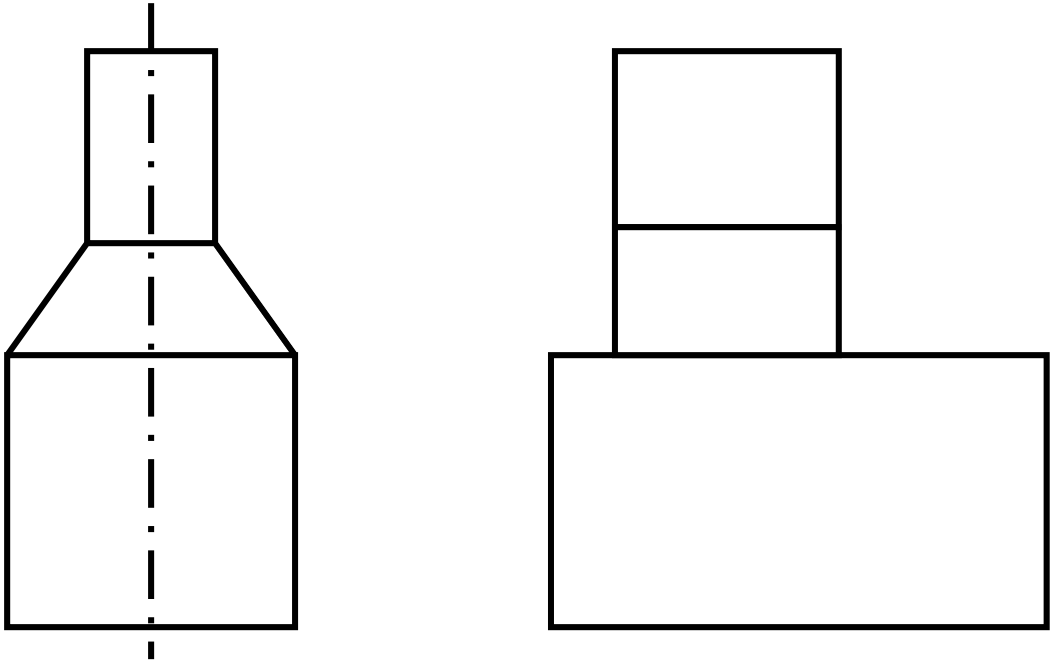
COULD BE THIS...



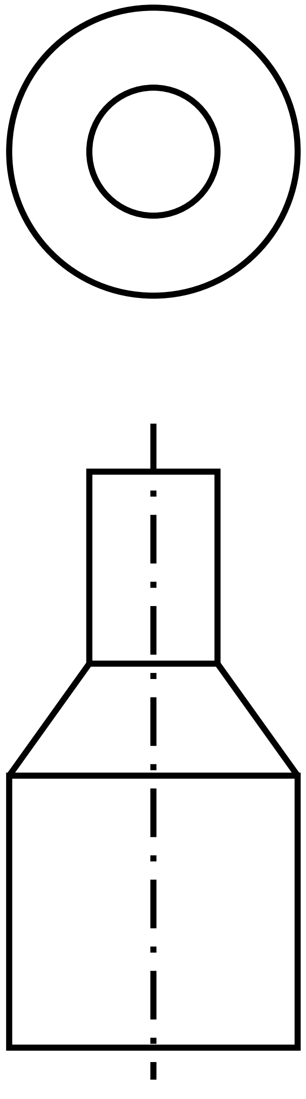


OR THIS

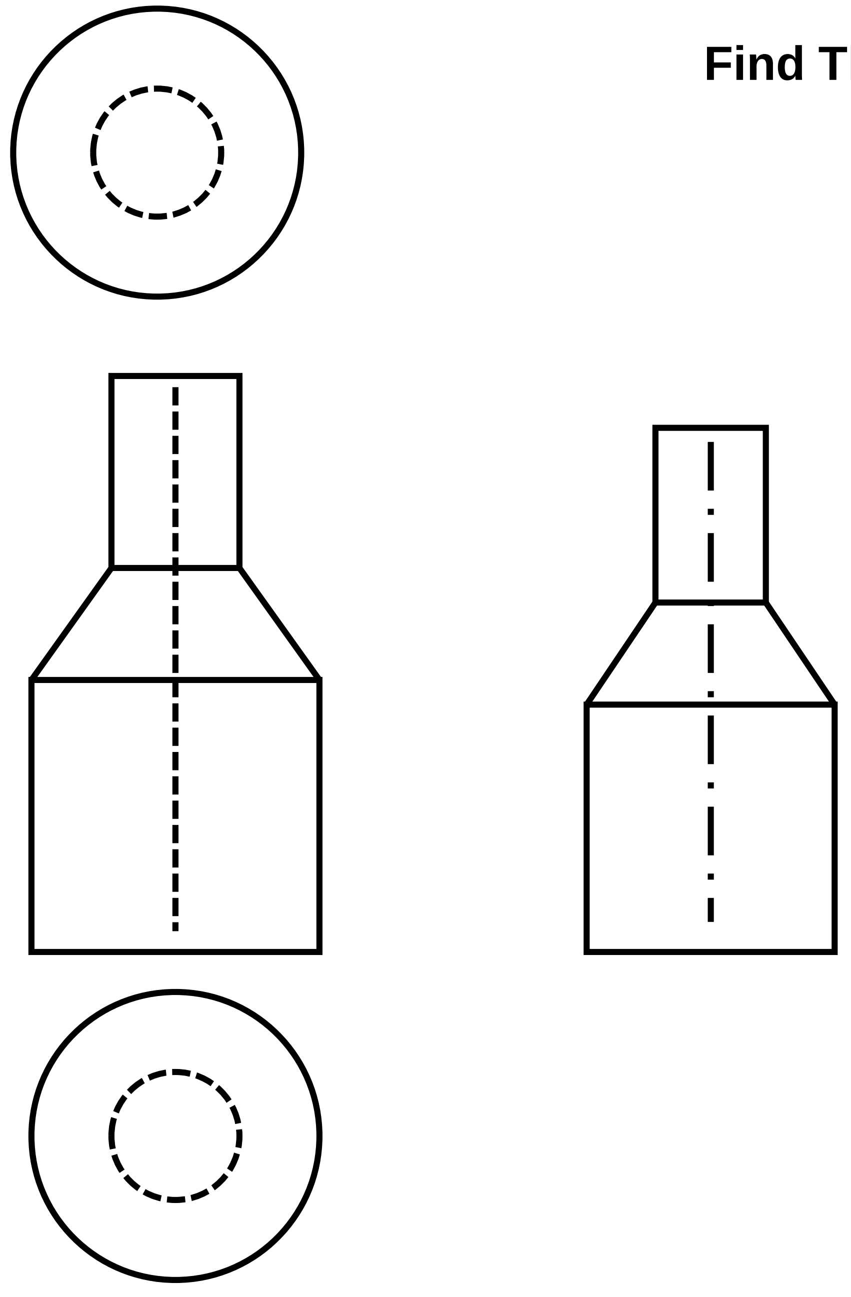
Centerlines imply symmetry,
NOT revolution *per se*



HERE, ONLY 2 VIEWS NEEDED
(Correct drawing)



Find The Mistakes!



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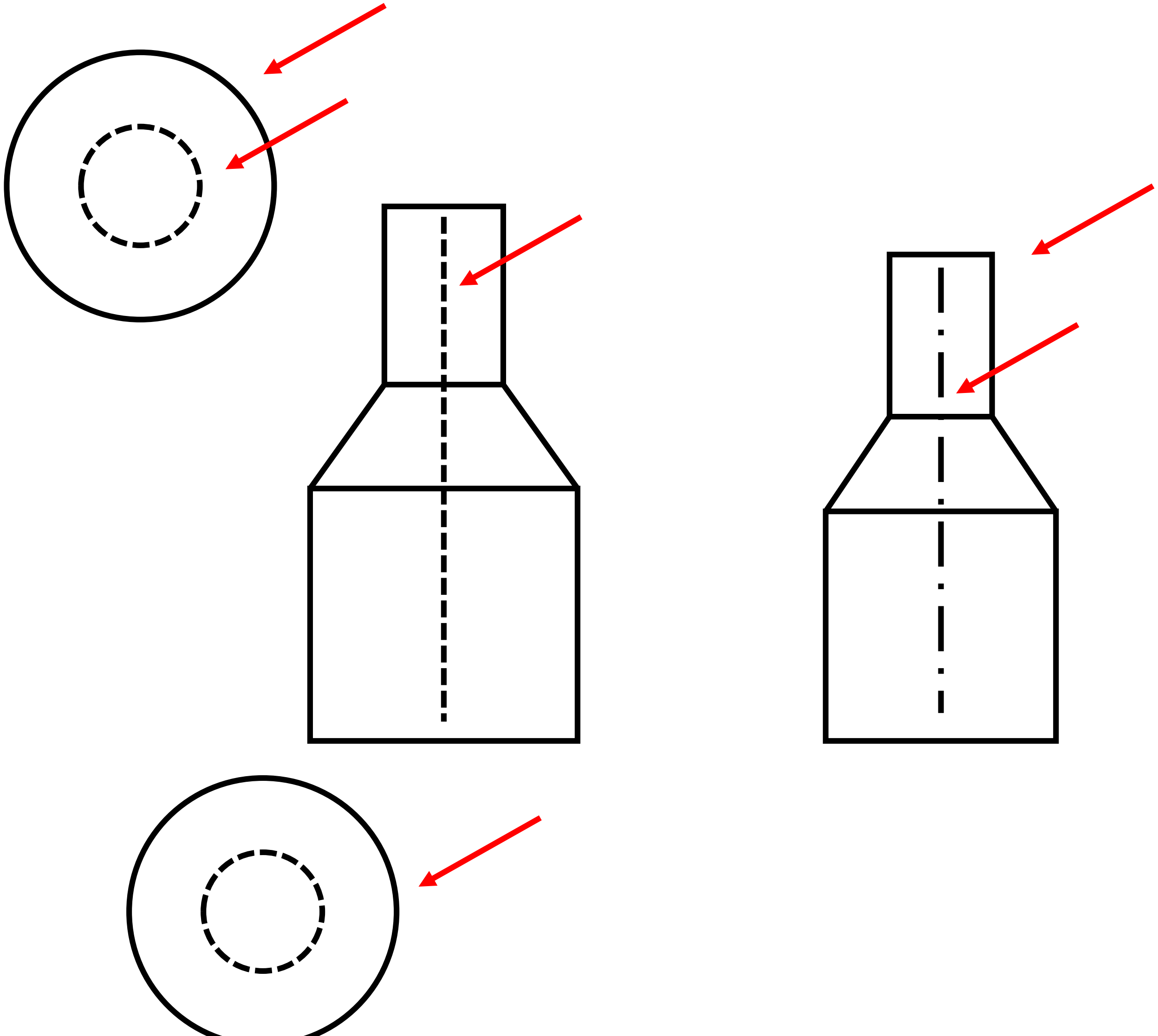
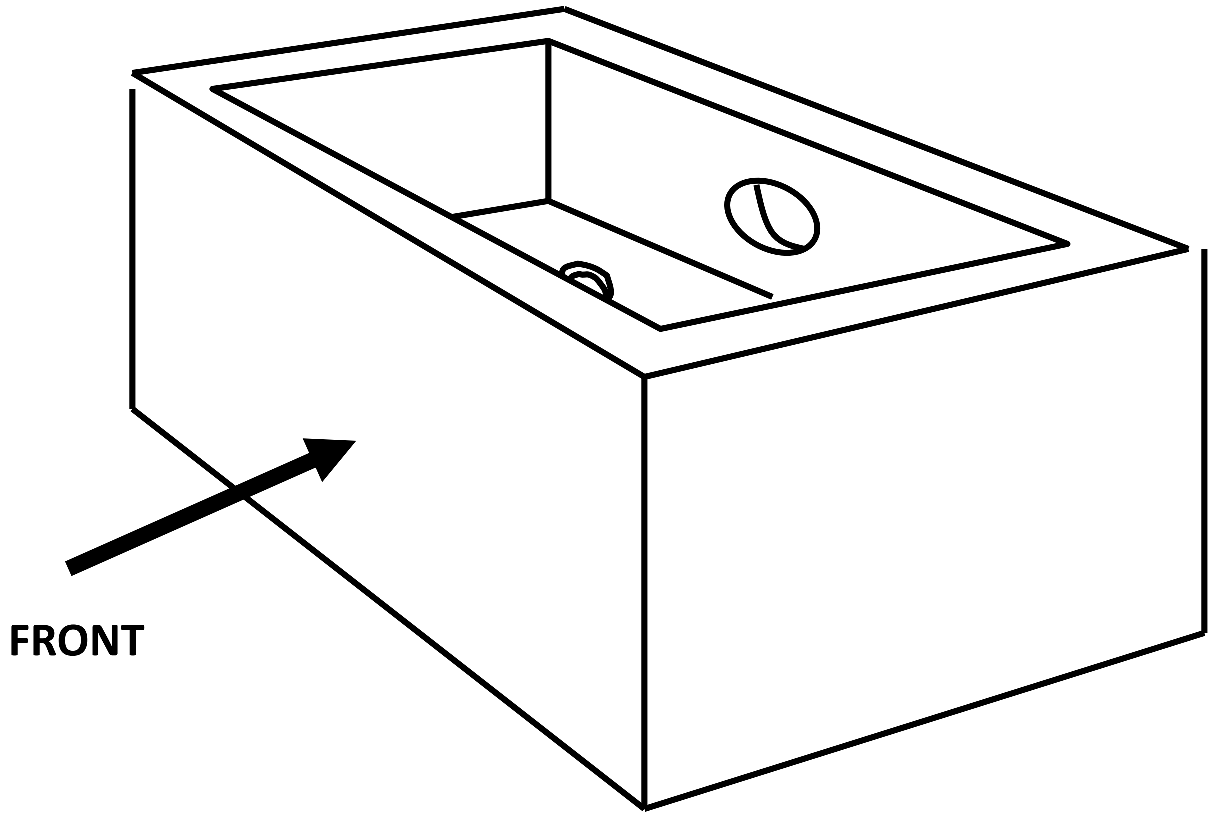
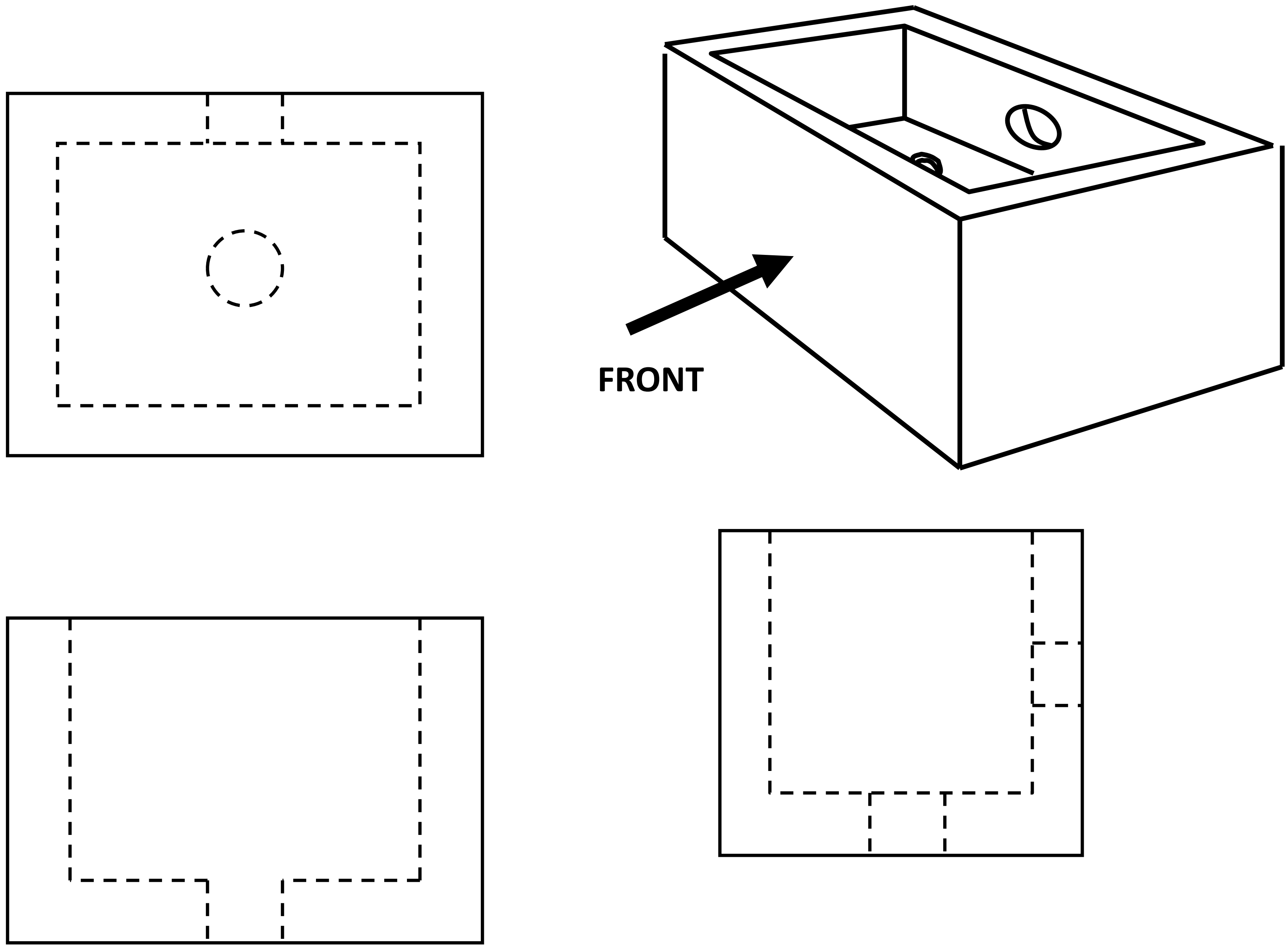
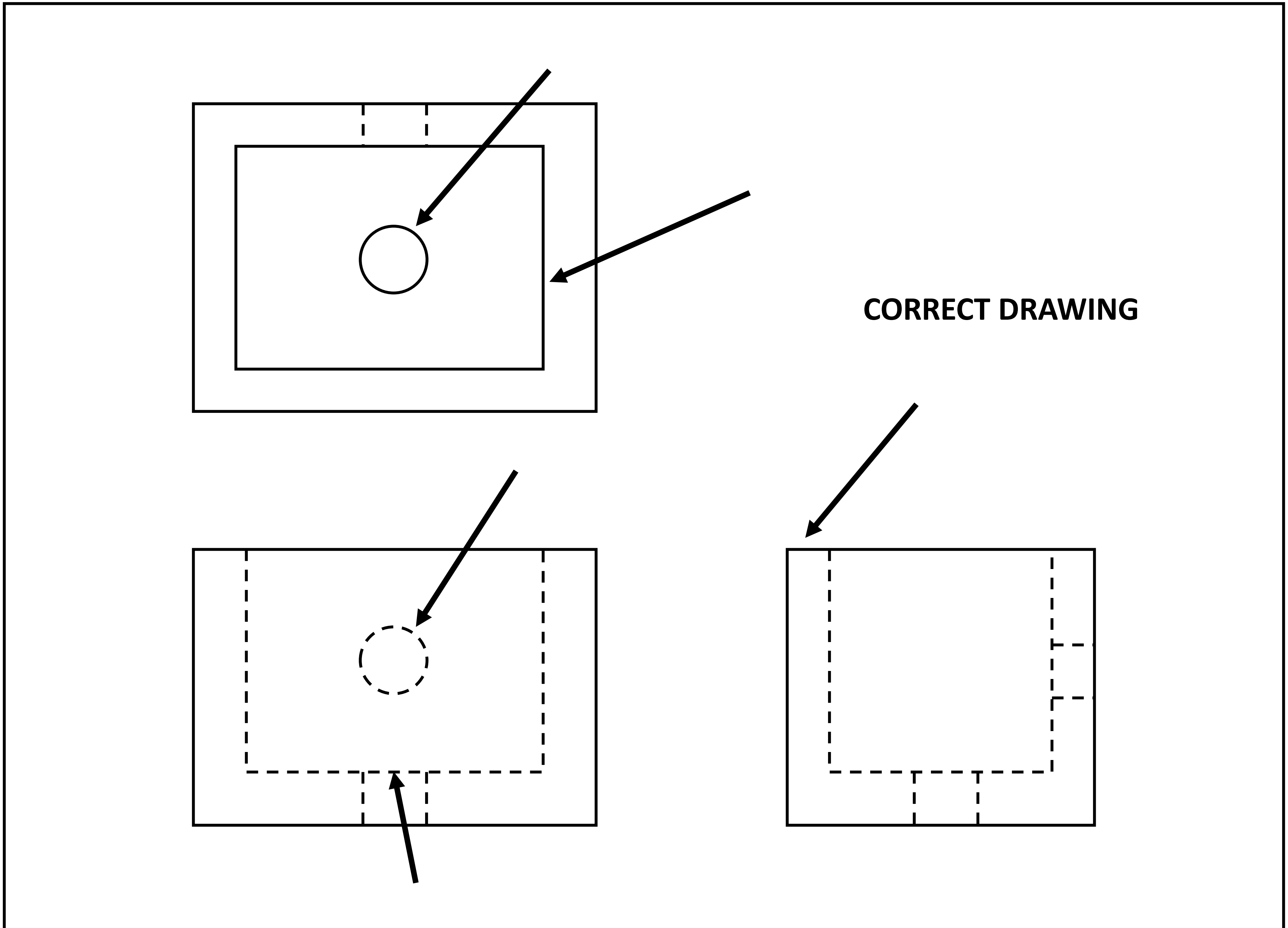


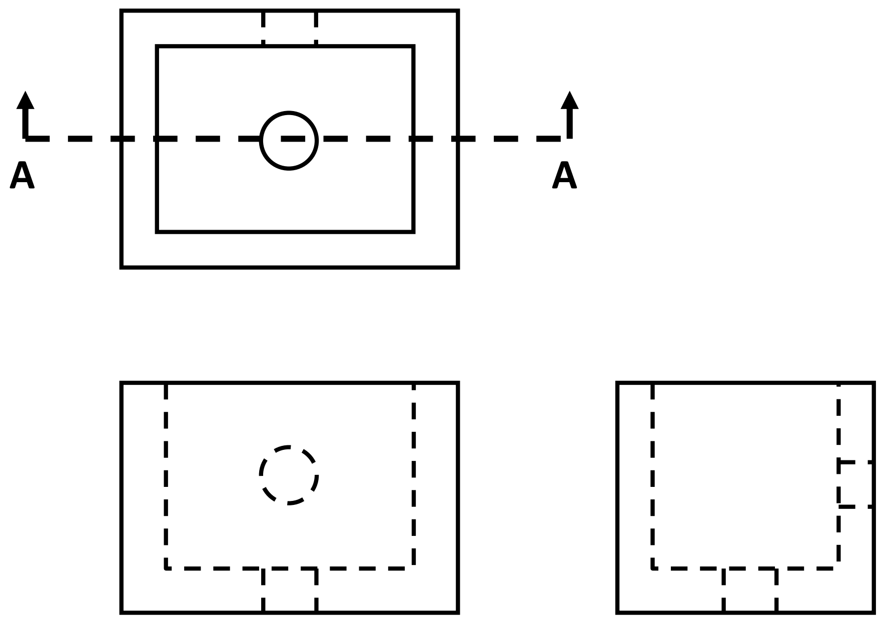

FRONT

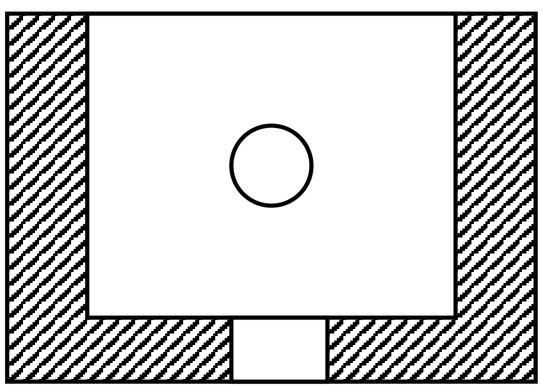


FIND THE MISTAKES!

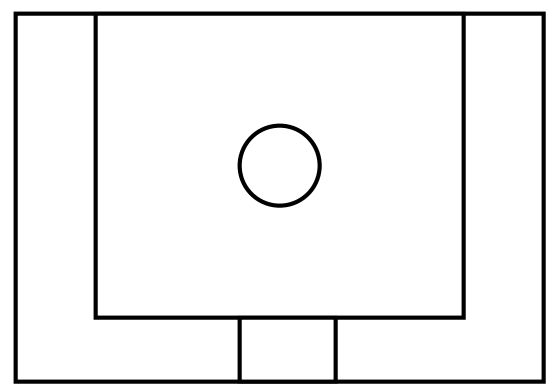

CORRECT DRAWING

SECTIONS

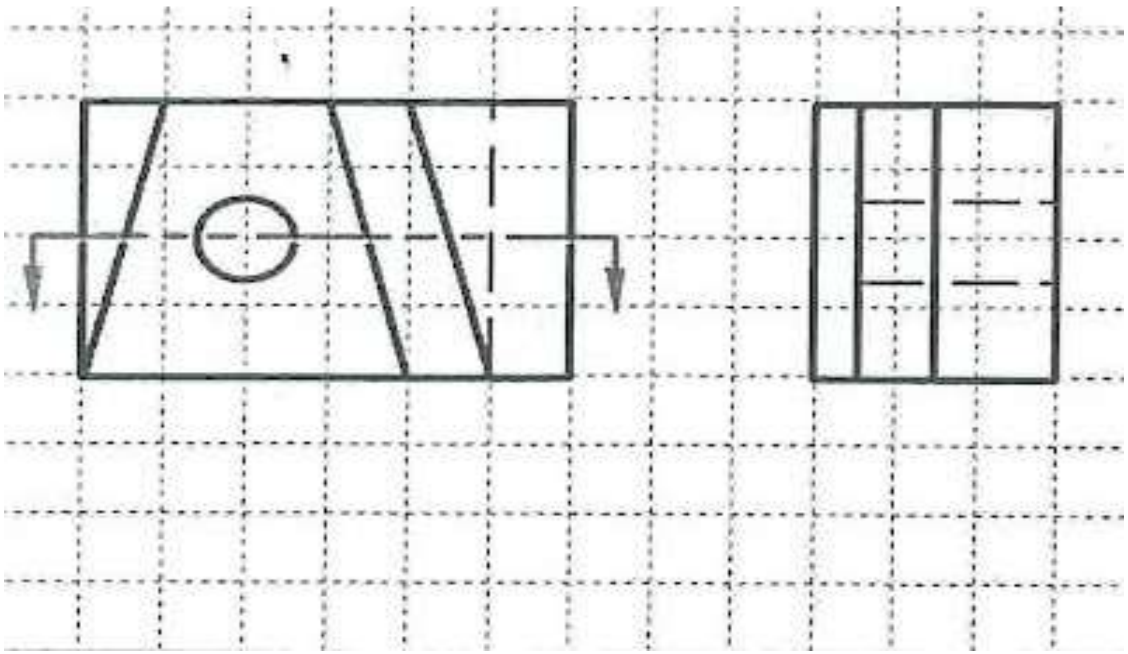




YES

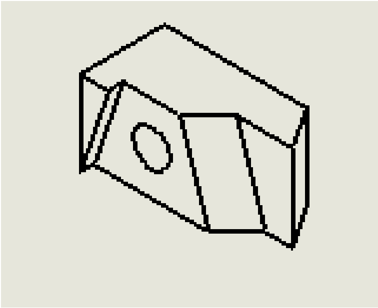


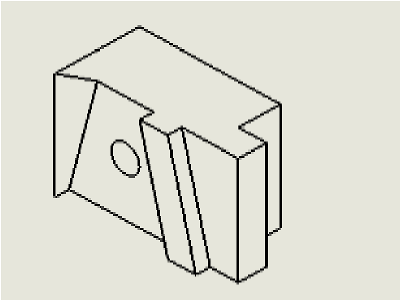
NO

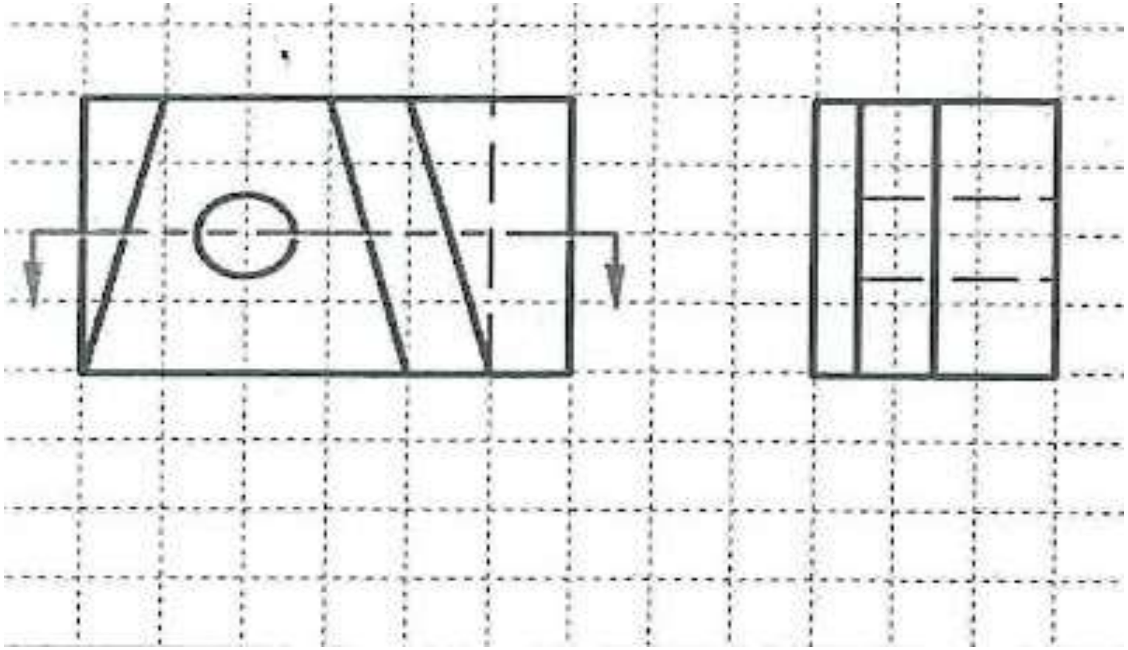


Working with person sitting next to you copy this and draw the **TOP VIEW**

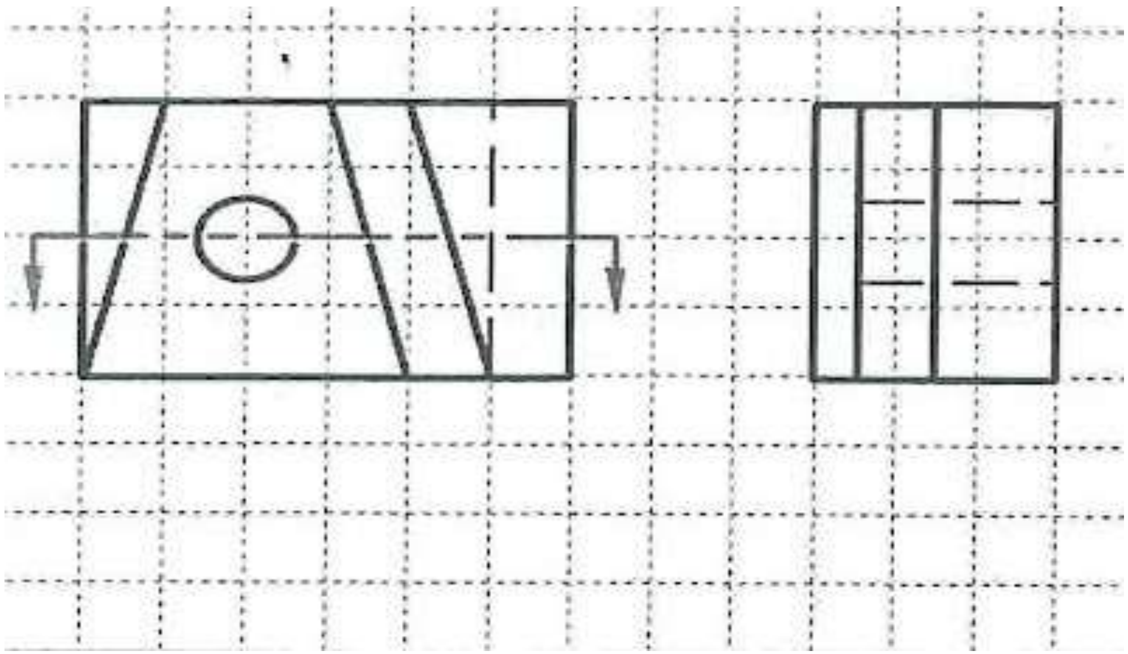
Possible Geometries



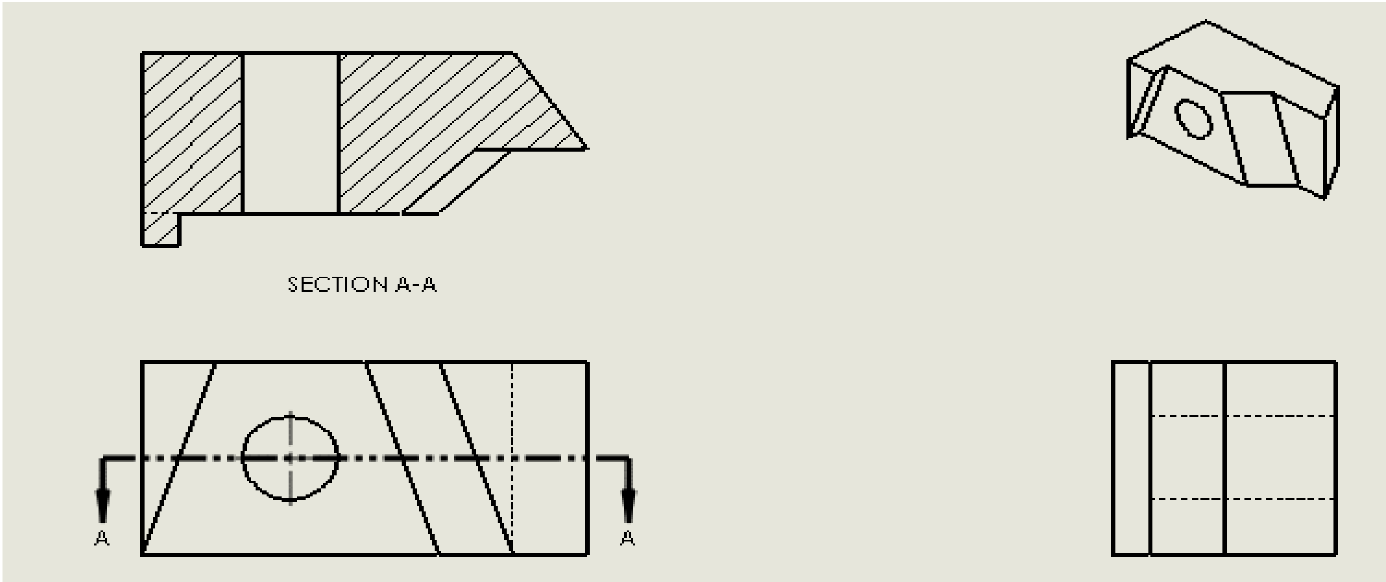




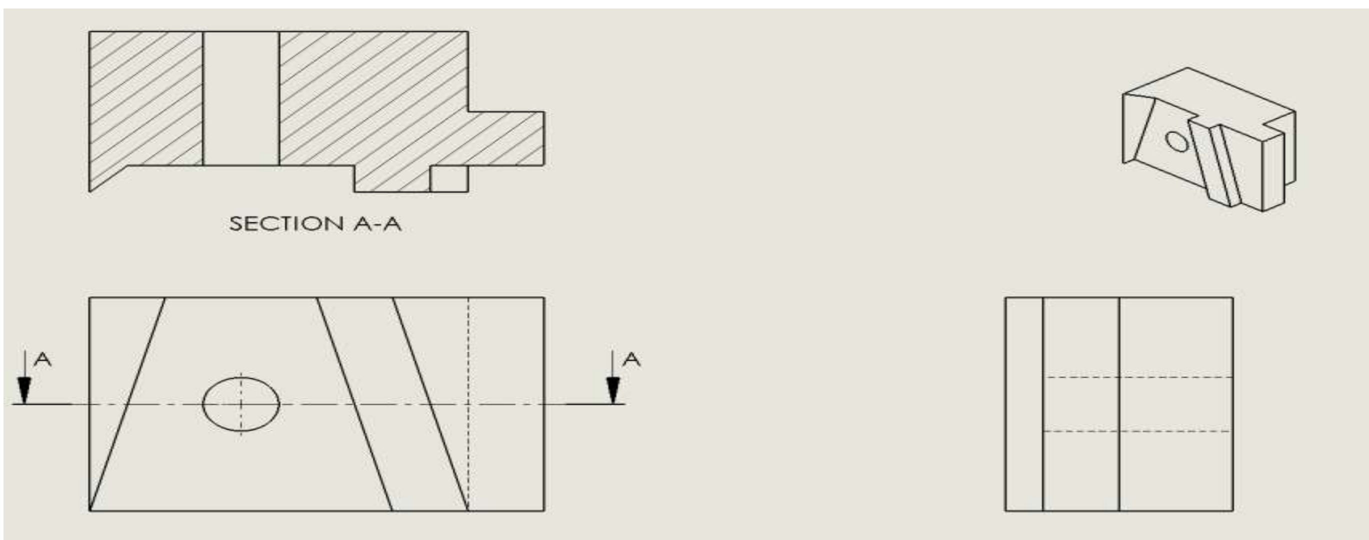
Working with person sitting next to you copy this and draw the **TOP VIEW**



Working with person sitting next to you, sketch the **Section View**

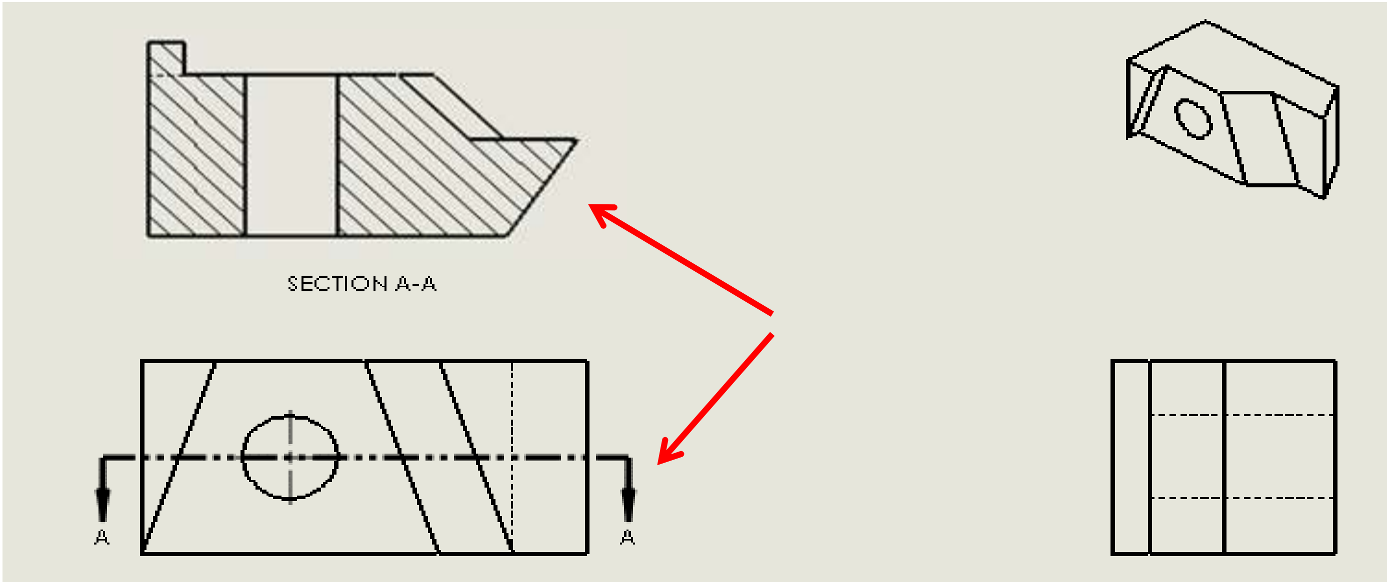


OK

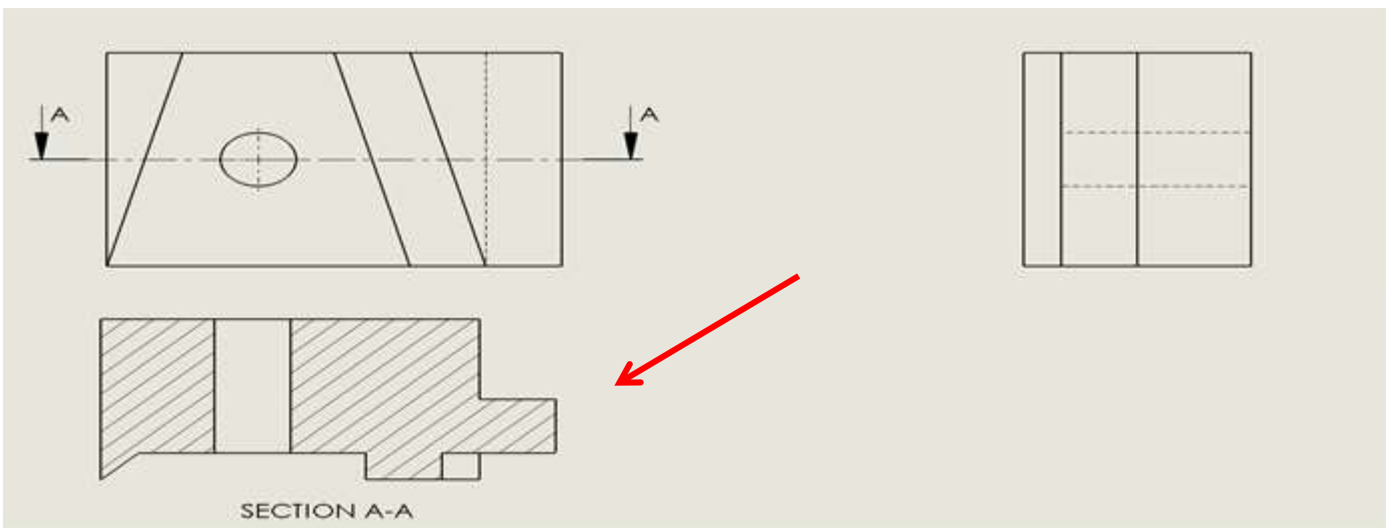


OK

Correct **Section Views**

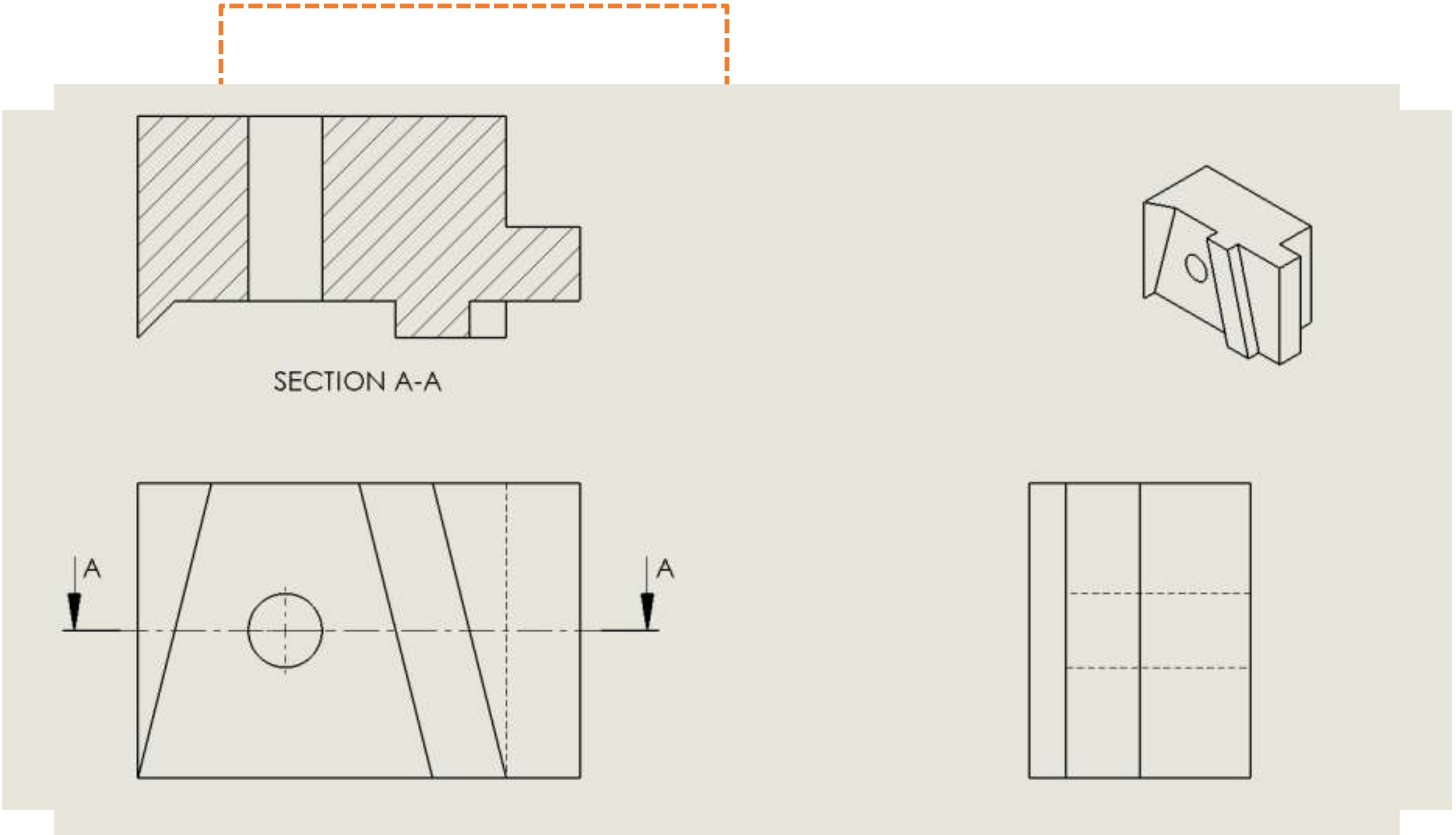


Wrong



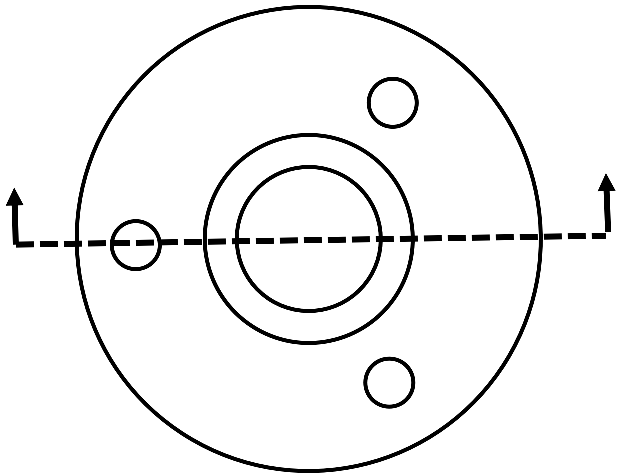
Wrong

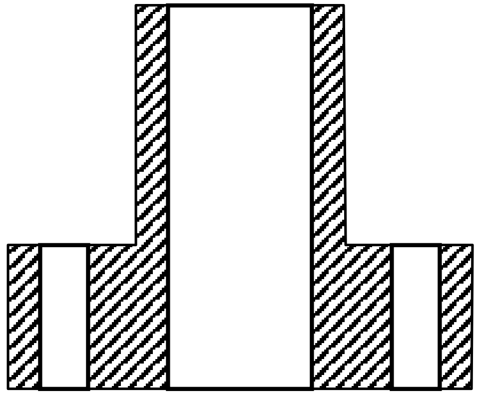
Working with person sitting next to you, Find the MISTAKES



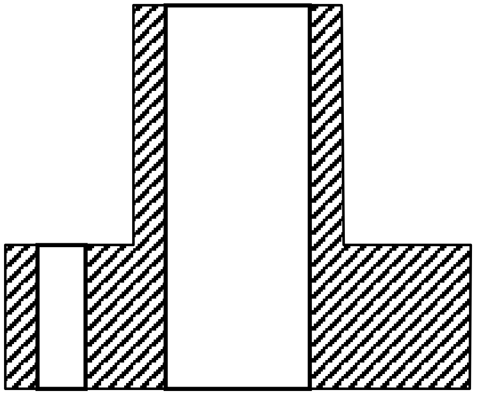
Working with person sitting next to you, sketch the **Section View**

REVOLVED SECTION





Preferred



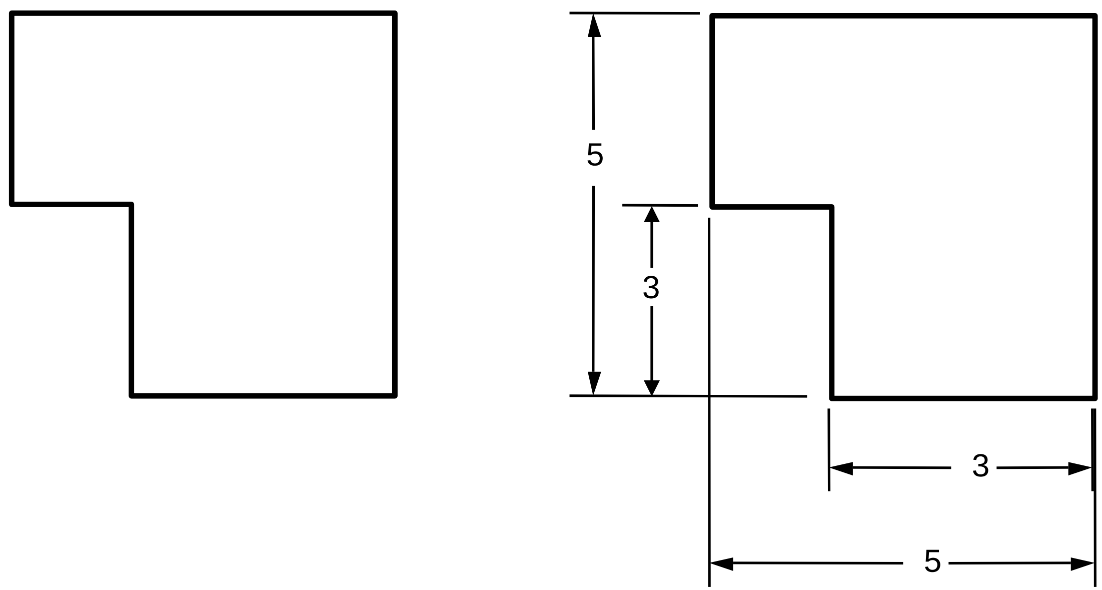
“True” section

DIMENSIONING

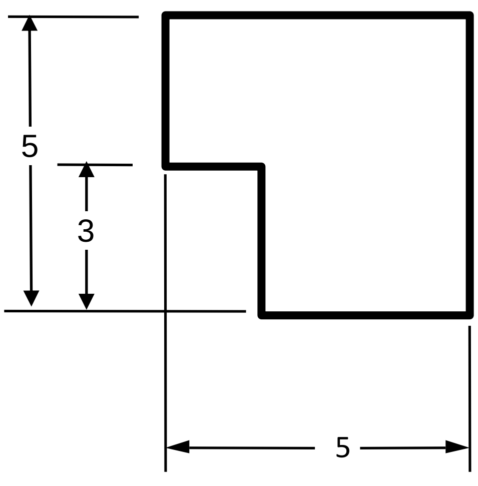
1. **SHAPE**
2. SIZE
3. **MATERIAL**
4. **TOLERANCE AND FINISH**

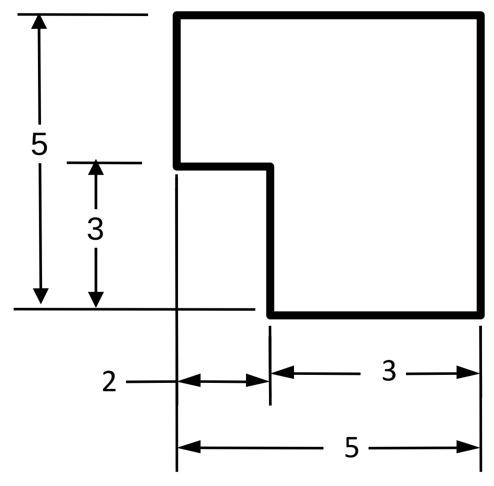
Dimensioning

- Conventions exist for choice and placement
- Not too many and not too few
- Never should measure off drawing with a ruler

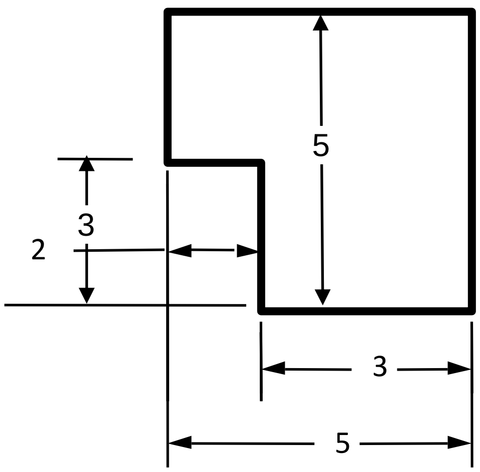


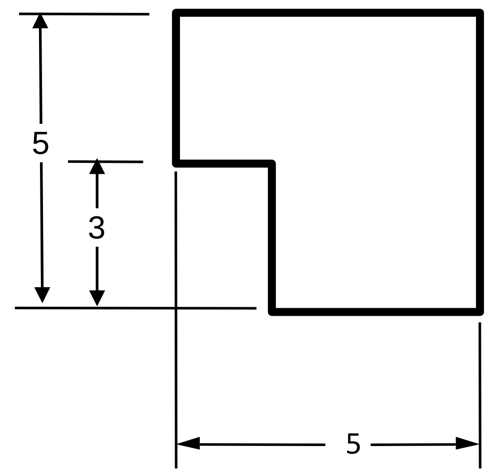
Under/Over Dimensioning



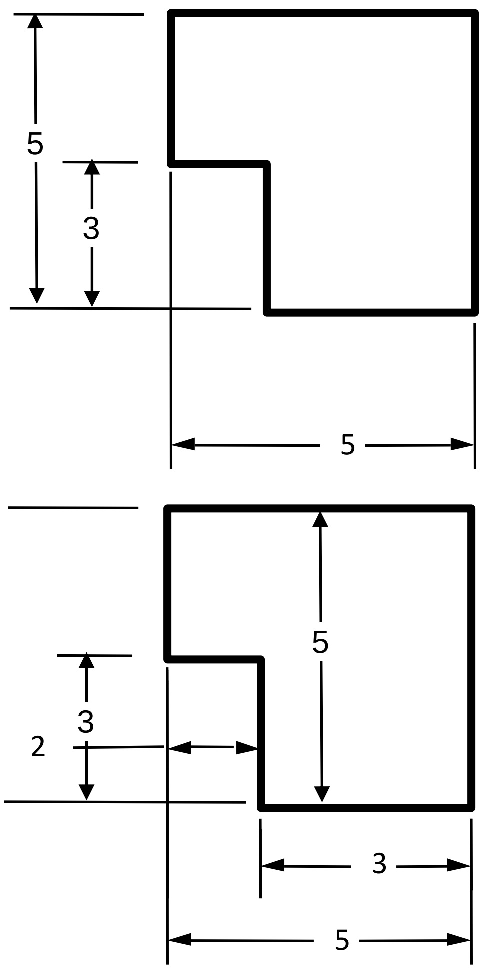


Dimensioning rules:
…find the mistakes.





Dimensioning guidelines

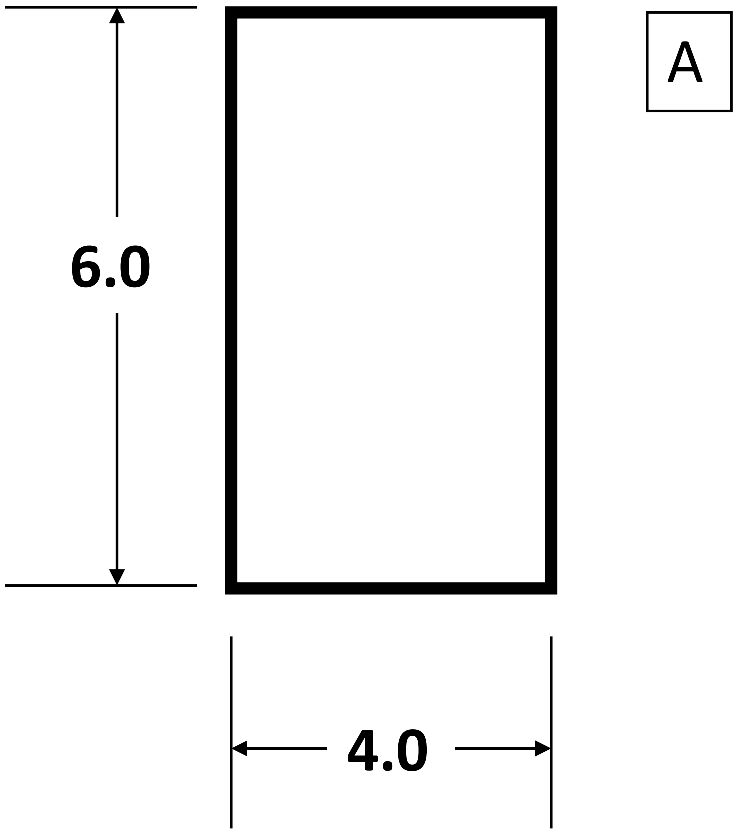


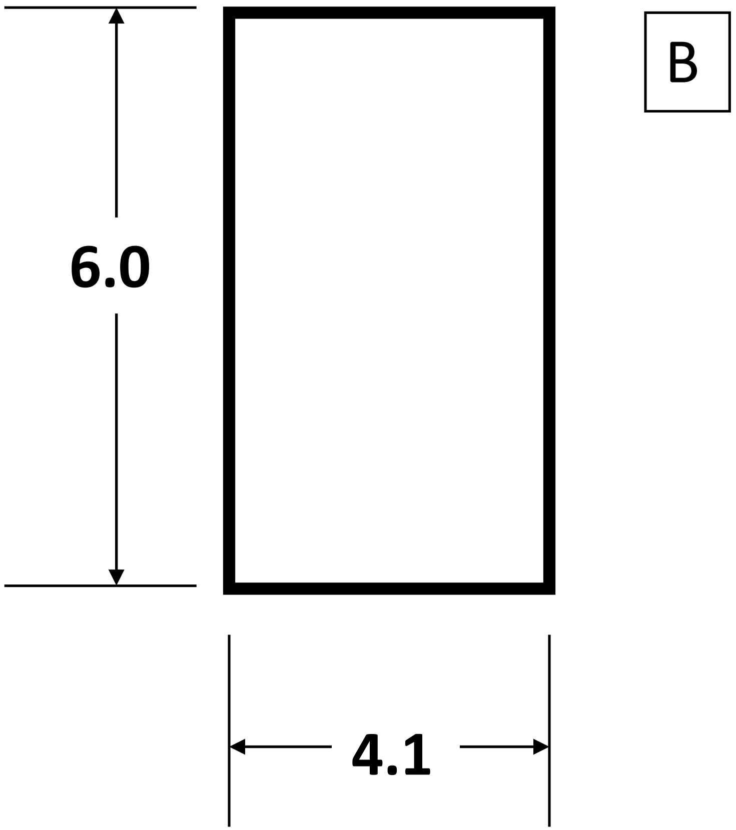
1. Don’t overdefine or underdefine the object. [MOST IMPORTANT]
2. Dimension to the visible contour or shape of the feature / Don’t dimension to hidden lines.
4. Don’t dimension to object lines (model edges), use extension lines.
5. Don’t overlap a dimension and the model. Place dimensions away from the model’s surface.
6. Don’t cross extension lines if possible.
7. Group dimensions when possible unless it become difficult to read.
8. Place dimensions on the side of the view were adjacent views exist (for easy referencing).

Design Detail

½" thick aluminum block

Which is more expensive: A or B and why?



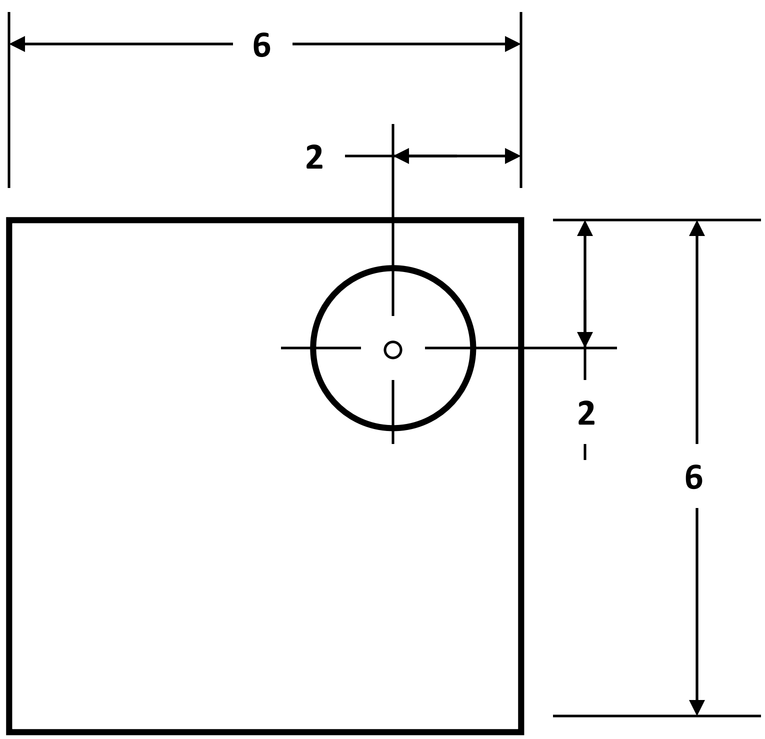


www.mcmaster.com

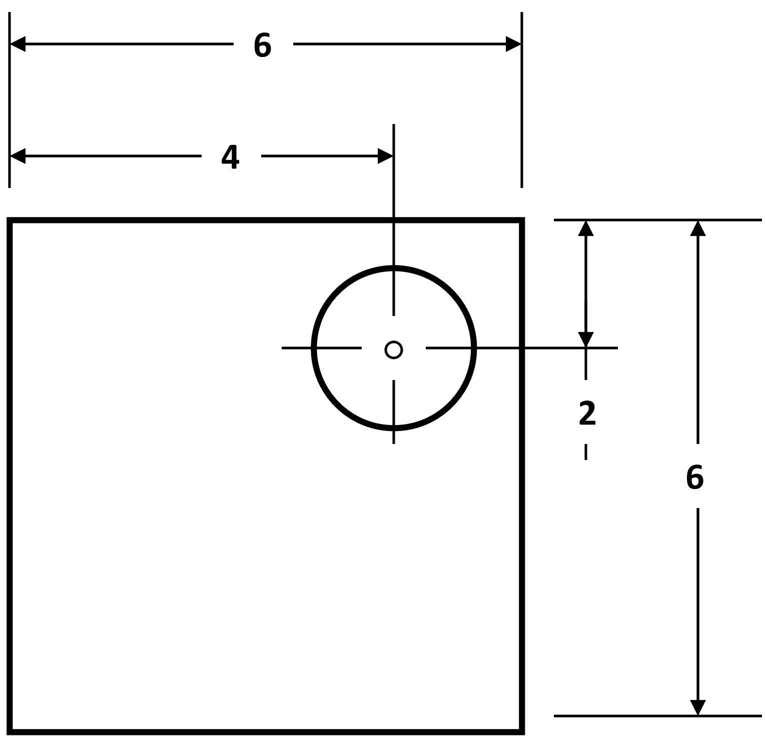
Dimensioning Choices & Design Intent

If change width of block to 8, what happens to the hole location?

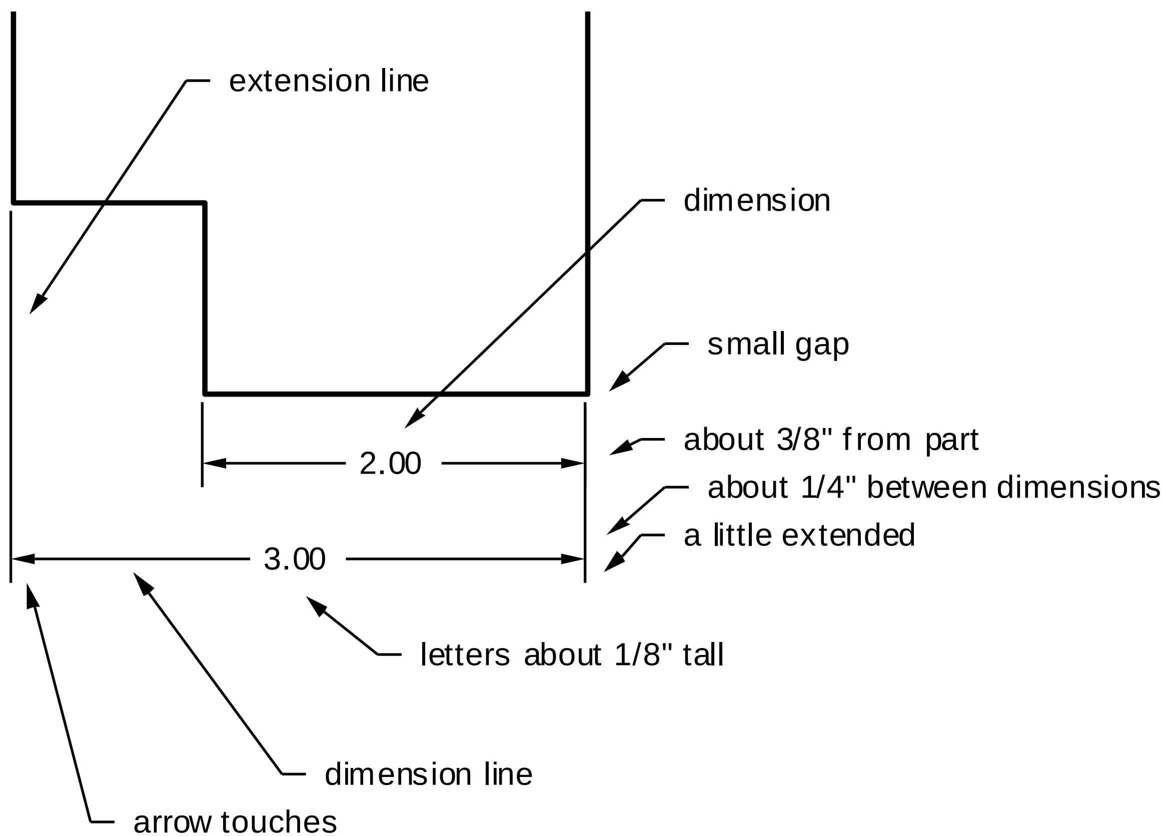
A

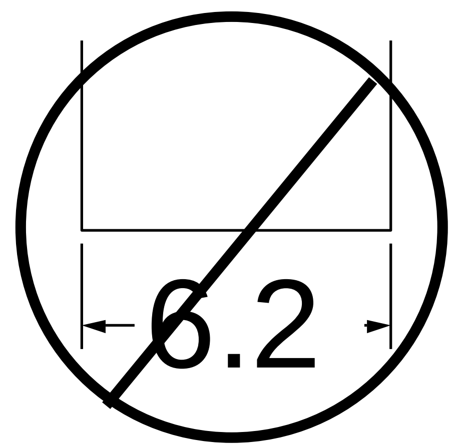


B

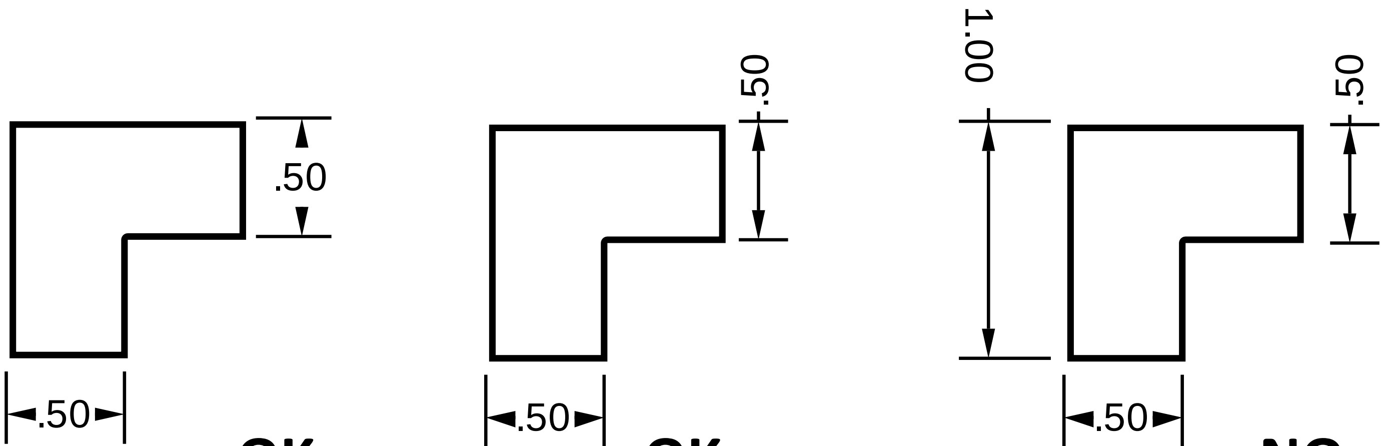


Placement conventions



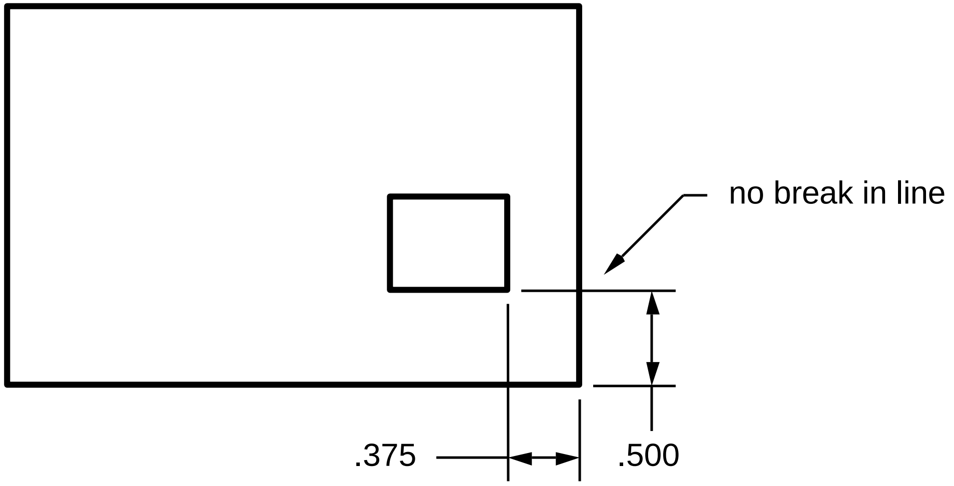


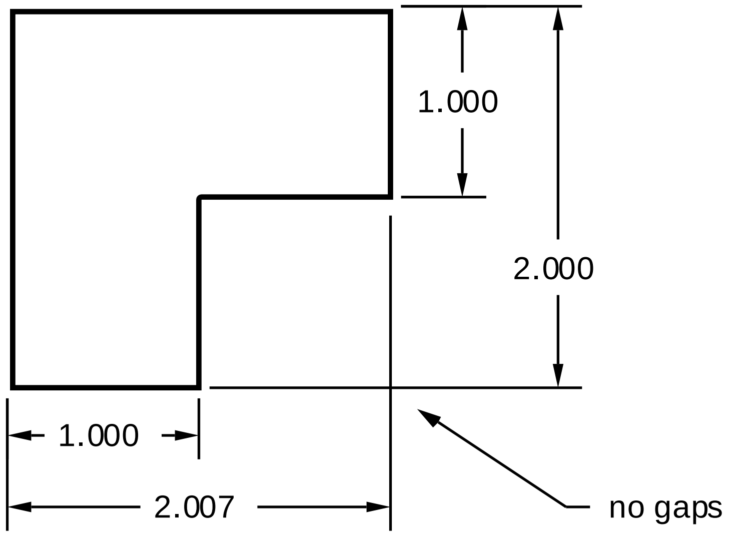
Lettering: 1 or 2 directions only



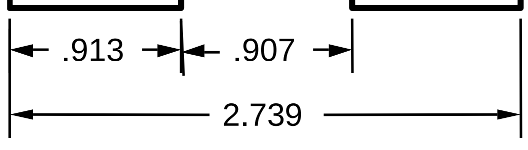
OK **OK** **NO**

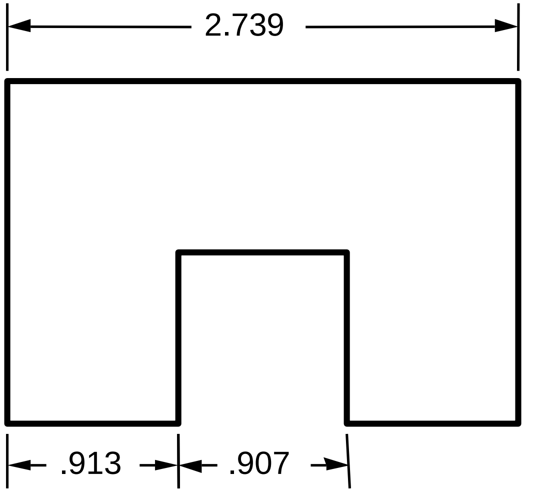
Extension Lines



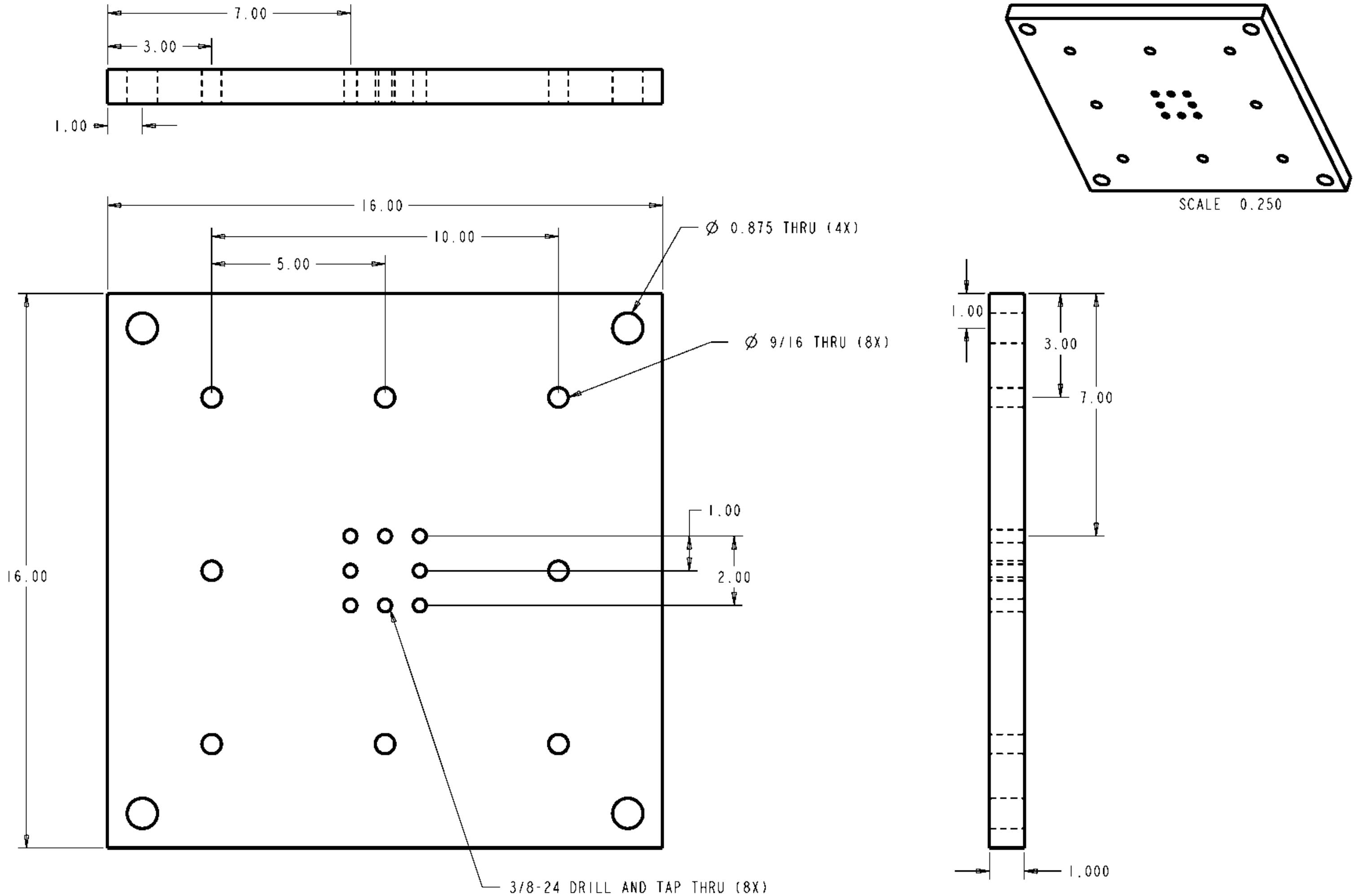


All on one side





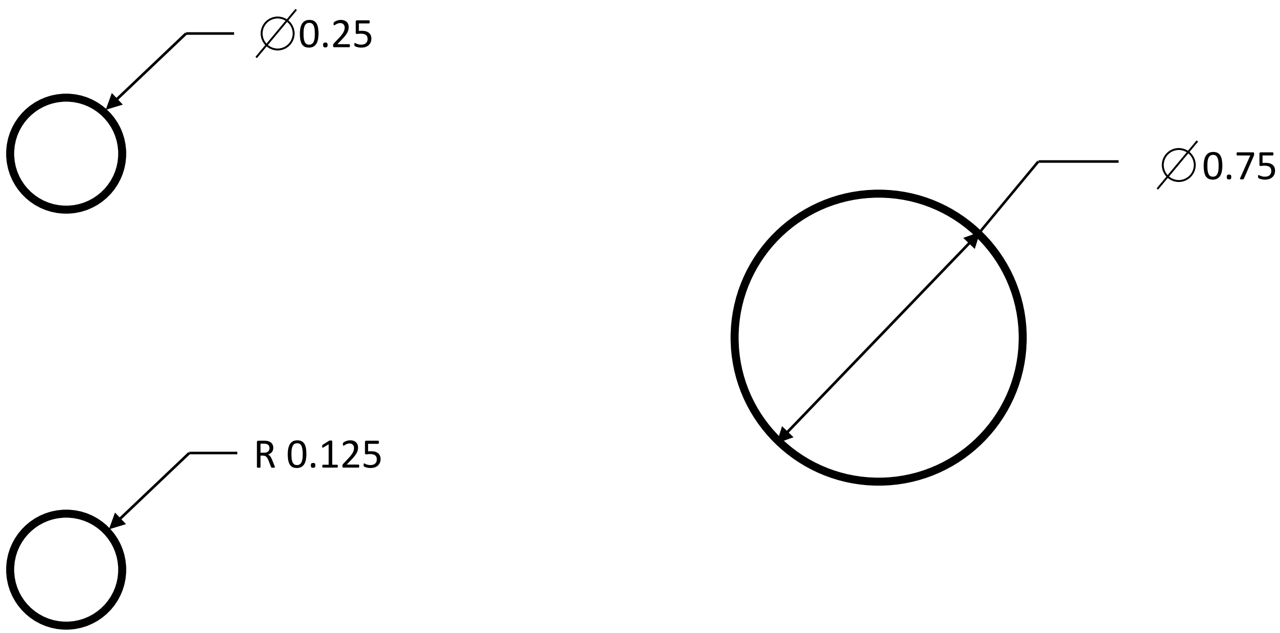
YES **NO**



NOTES:
1. PAINT FLAT BLACK (1 PRIMER, 2 FINISH COATS)
2. TOLERANCES: ± 0.01, EXCEPT HOLE PATTERNS ± 0.05
3. CORNER HOLES (4 X) MATCH HOLES ON SUPPORT BLOCKS
4. OUTER PATTERN OF HOLES (8 X) MATCHES PATTERN ON STRIKE PLATE
5. INNER PATTERN OF HOLES (8 X) MATCHES PATTERN ON SENSOR BLOCK

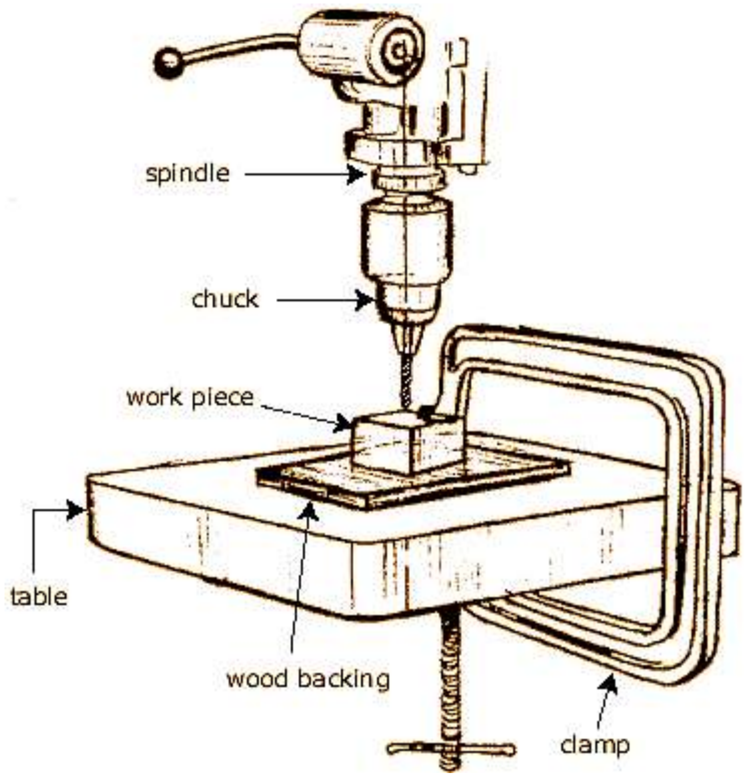
CHOPPING SIMULATOR	TOP PLATE	
	MATERIAL: MILD STEEL	
Designed by W. Durfee 612-625-0099 wkdurfee@umn.edu	SCALE: 0.500	DIMENSIONS IN INCHES
	DRW by: WKD	DATE: 16-Jul-03

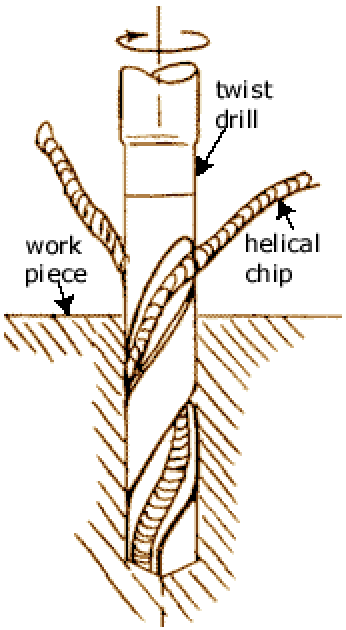
Dimensioning Rounds



Place dimension on view that shows the circle
Show diameter rather than radius

TOLERANCES





www.efunda.com/processes/machining/drill.cfm

www.efunda.com/processes/machining/drill_press.cfm

Tolerances

- Matter because parts cannot be made to an exact dimension
- Must specify dimension tolerance so that every part A fits every part B
- Higher tolerance = higher cost
- A ½ inch hole made on an ordinary drill press gives you a hole in the range 0.496 to 0.504 (+/- 0.004). For higher precision, drill undersize and use a reamer…but it will cost you more and take longer to fabricate.

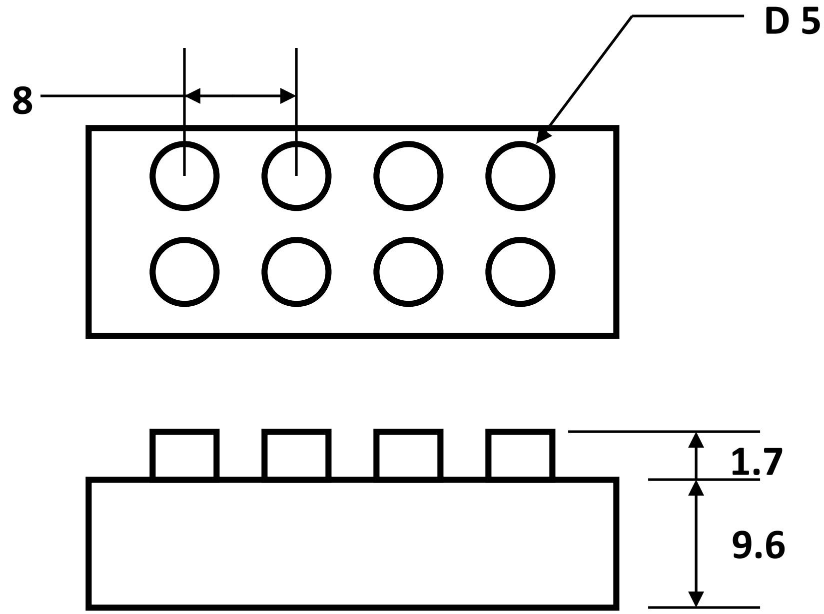
½ inch drill bit: +/- .0040

½ inch reamer: +.0003, -.0000

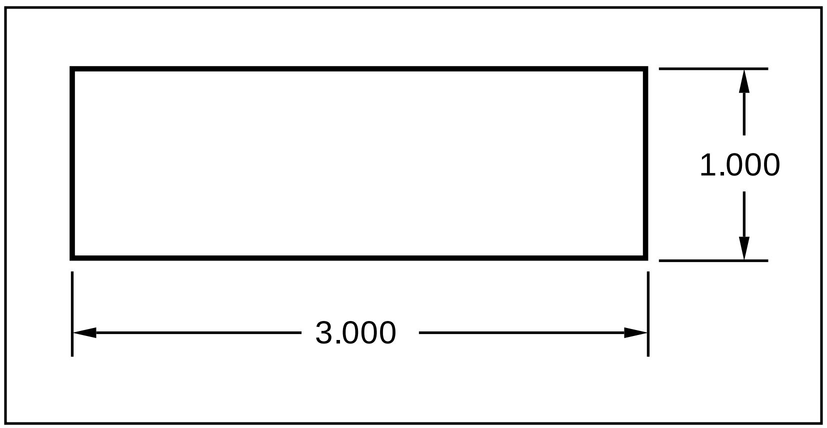
LEGOS !

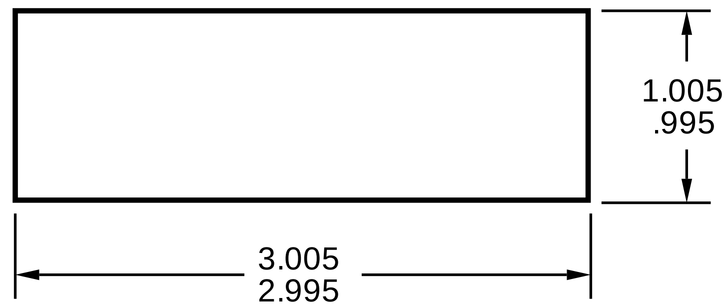
ABS plastic

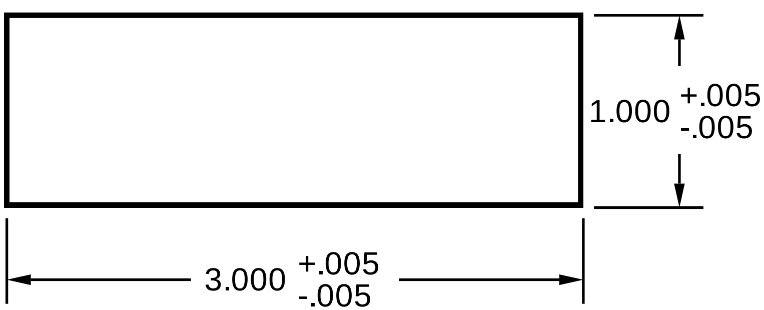
- You can combine six 8-stud bricks of the same color 102,981,500 different ways
- 91% of all households with children in Denmark own LEGO products
- During the period 1949-1990, 110,000,000,000 (110 billion) LEGO elements were molded
- Bayer Corporation's Polymers Division is the official supplier of ABS plastic to the LEGO group.
- Exact specifications of the Bayer resin supplied to the LEGO Group are a closely held secret.
- Dimension tolerance of mold is 0.005 mm (0.0002 inch)!

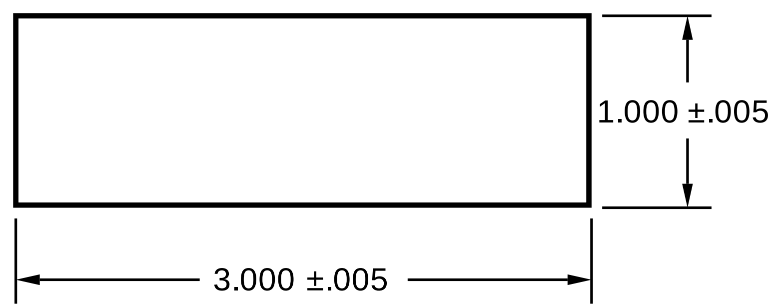


Representing tolerances



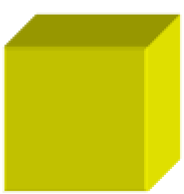






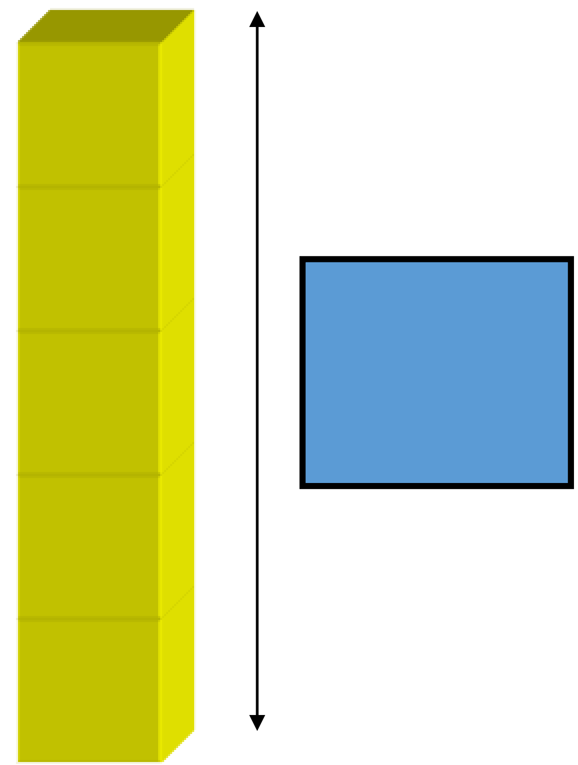
Tolerance stack-up

What is min and max height of stack?

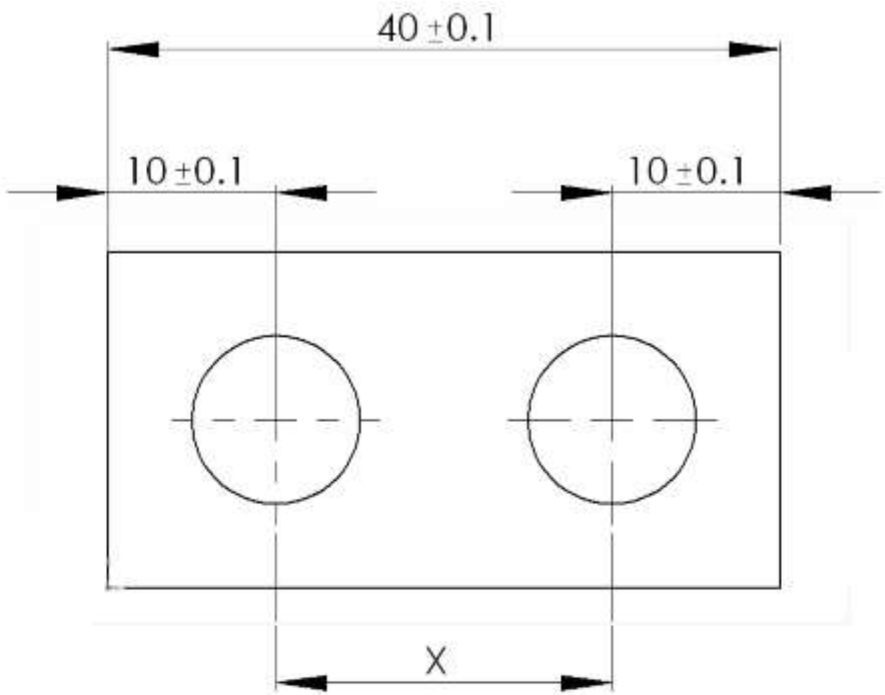


3.0 $\pm$ .05

5 high stack

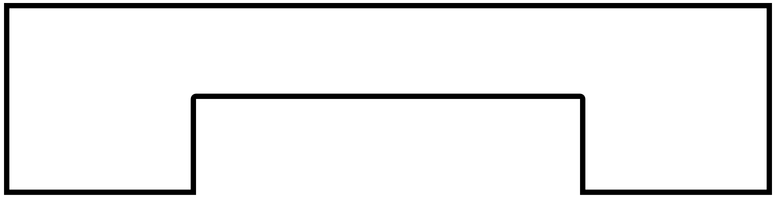


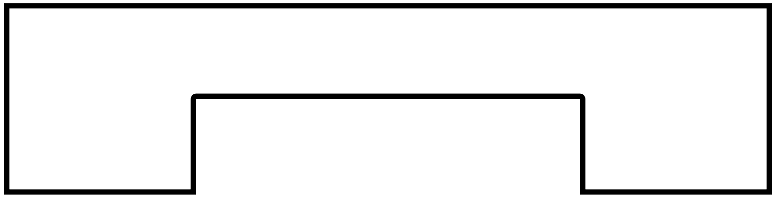
Tolerance Stacking

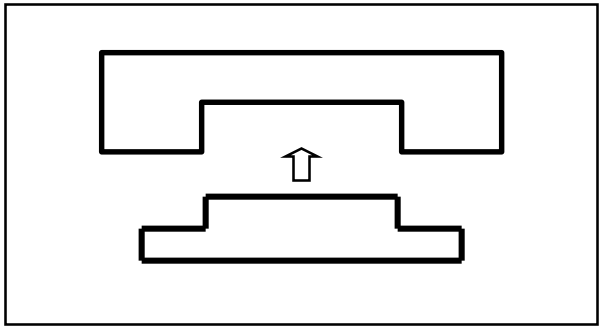


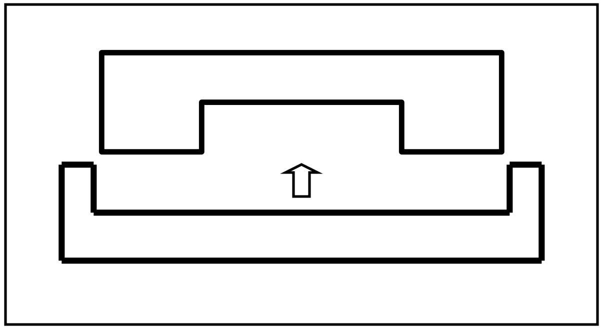
What's the tolerance (+/-) on dimension x?

Chain or Baseline Dimensioning?
… You decide

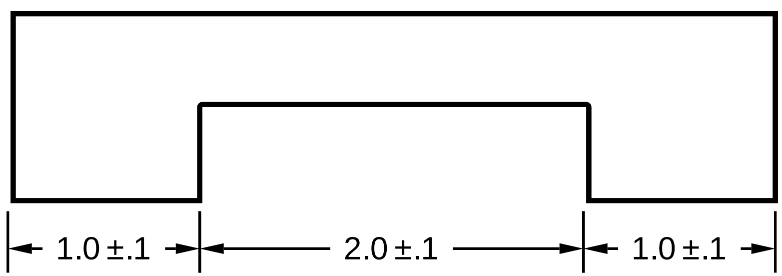


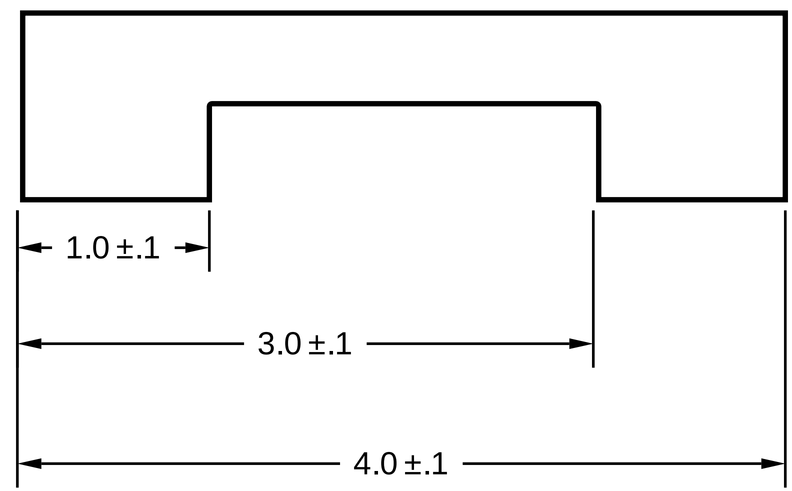


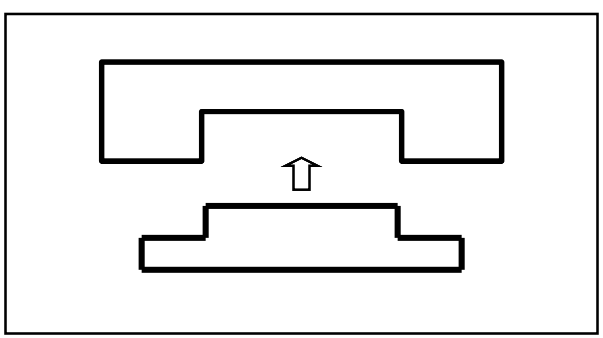


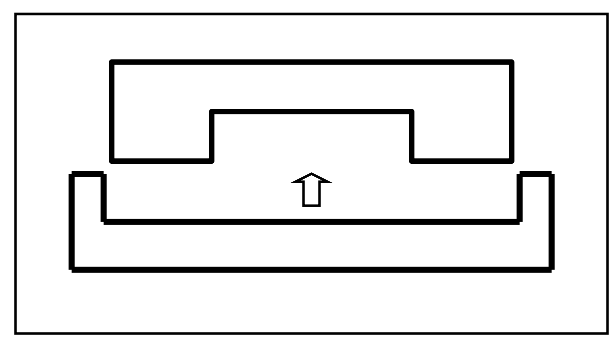


Chain or Baseline Dimensioning



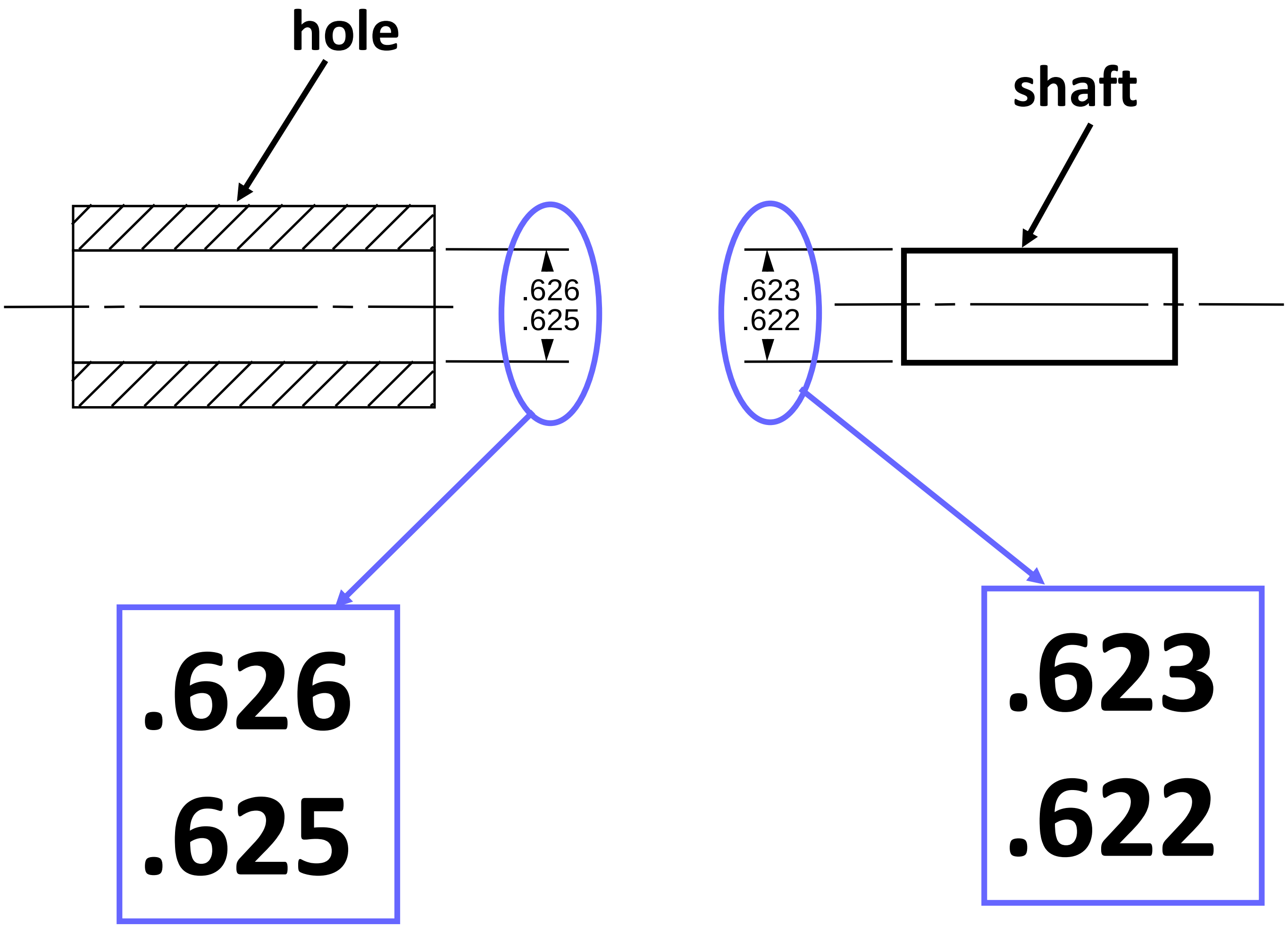


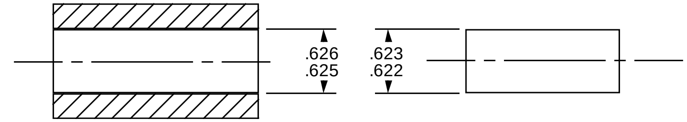




Holes and shafts

1. Will all shafts fit into all holes?
2. What is maximum clearance?





ANSI standards for shaft & holes

Clearance	Shaft smaller than hole for all shafts and holes
Interference	Shaft larger than hole for all shafts and holes
Transition	Smallest shaft fits in largest hole

Running/Sliding	RC1 (fit together, no play) to RC9 (fit loosely)
Force/shrink	FN1 (light drive and pressure) to FN5 (high stresses and pressures)
…and others	Like Locational, etc.

Basic hole	Use nominal size of hole as starting point
Basic shaft	Use nominal size of shaft as starting point

Preferred Fit Example…

Running and Sliding Fits - American National Standards

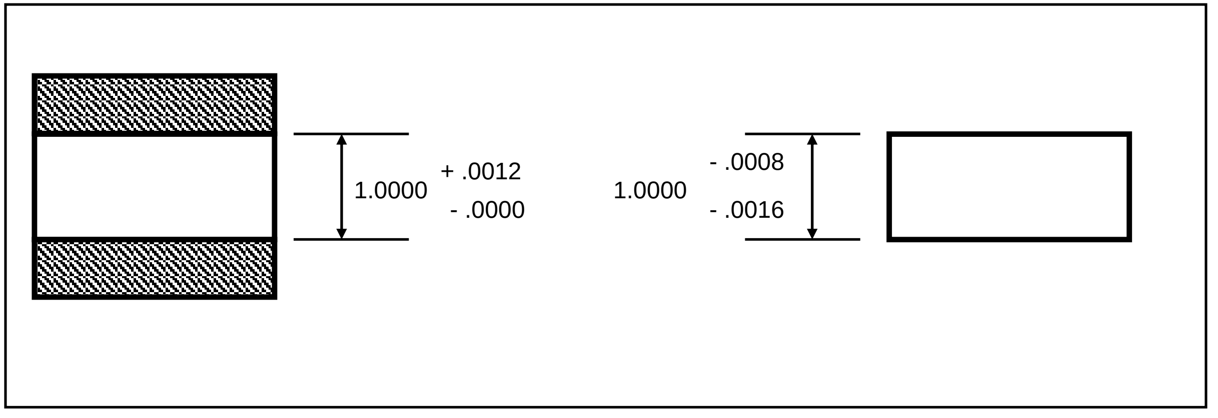
RC 5, RC 6 — ***Medium runnings fits*** are intended for higher running speeds, or heavy journal pressures or both

RC 7 — ***Free running fits*** are intended for use where accuracy is not essential, or where large temperature variations are likely to be encountered, or under both these conditions

RC 8, RC 9 — ***Loose running fits*** are intended for use where wide commercial tolerances may be necessary, together with an allowance on the external member

Nominal Size Range, Inches	Class RC5			Class RC6			Class RC7			Class RC8			Class RC9		
	Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits	
		Hole	Shaft		Hole	Shaft		Hole	Shaft		Hole	Shaft		Hole	Shaft
Over To		H8	e7		H9	e8		H9	d8		H10	e9		H11	
0-0.12	0.6 1.6	+0.6 -0	-0.6 -1.0	0.6 2.2	+1.0 -0	-0.6 -1.2	1.0 2.6	+1.0 -0	-1.0 -1.6	2.5 5.1	+1.6 -0	-2.5 -3.5	4.0 8.1	+2.5 -0	-4.0 -5.6
0.12-0.24	0.8 2.0	+0.7 -0	-0.8 -1.3	0.8 2.7	+1.2 -0	-0.8 -1.5	1.2 3.1	+1.2 -0	-1.2 -1.9	2.8 5.8	+1.8 -0	-2.8 -4.0	4.5 9.0	+3.0 -0	-4.5 -6.0
0.24-0.40	1.0 2.5	+0.9 -0	-1.0 -1.6	1.0 3.3	+1.4 -0	-1.0 -1.9	1.6 3.9	+1.4 -0	-1.6 -2.5	3.0 6.6	+2.2 -0	-3.0 -4.4	5.0 10.7	+3.5 -0	-5.0 -7.2
0.40-0.71	1.2 2.9	+1.0 -0	-1.2 -1.9	1.2 3.8	+1.6 -0	-1.2 -2.2	2.0 4.6	+1.6 -0	-2.0 -3.0	3.5 7.9	+2.8 -0	-3.5 -5.1	6.0 12.8	+4.0 -0	-6.0 -8.5
0.71-1.19	1.6 3.6	+1.2 -0	-1.6 -2.4	1.6 4.8	+2.0 -0	-1.6 -2.8	2.5 5.7	+2.0 -0	-2.5 -3.7	4.5 10.0	+3.5 -0	-4.5 -6.5	7.0 15.5	+50 -0	-7.0 -10.5
1.19-1.97	2.0 4.6	+1.6 -0	-2.0 -3.0	2.0 6.1	+2.5 -0	-2.0 -3.6	3.0 7.1	+2.5 -0	-3.0 -4.6	5.0 11.5	+4.0 -0	-5.0 -7.5	8.0 18.0	+6.0 -0	-8.0 -12.0
1.97-3.15	2.5 5.5	+1.8 -0	-2.5 -3.7	2.5 7.3	+3.0 -0	-2.5 -4.5	4.0 8.8	+3.0 -0	-4.0 -5.8	6.0 13.5	+4.5 -0	-6.0 -9.0	9.0 20.5	+7.0 -0	-9.0 -13.5

“Basic Hole” Tolerancing Example



Drawing shows 1 in. nominal, ANSI RC4 clearance fit

“Basic Hole” means smallest possible hole = nominal, then size shaft for clearance

RC4 clearance = [0.0008, 0.0028] = [smallest hole-largest shaft,

largest hole - smallest shaft]

Title block information for tolerance

ALL DIMENSIONS IN INCHES

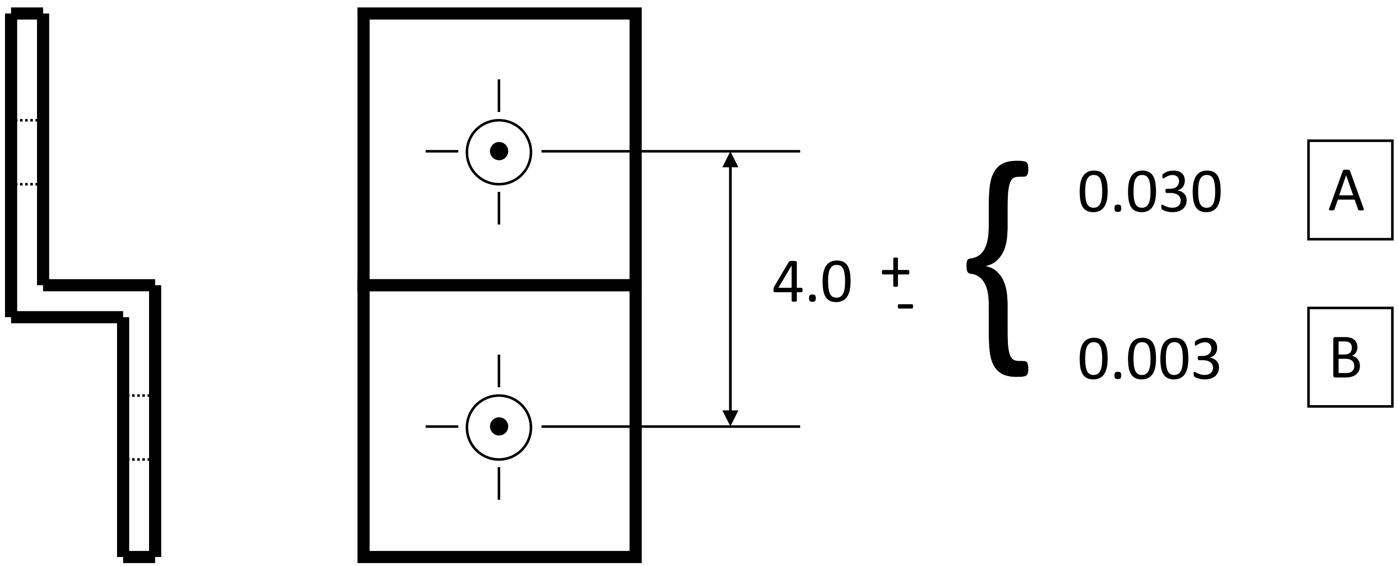
HOLD ALL DIMENSIONS TO ± 0.010 UNLESS SPECIFIED

Dimension	**Tolerance**
X.X	± 0.1
X.XX	± 0.05
X.XXX	± 0.001

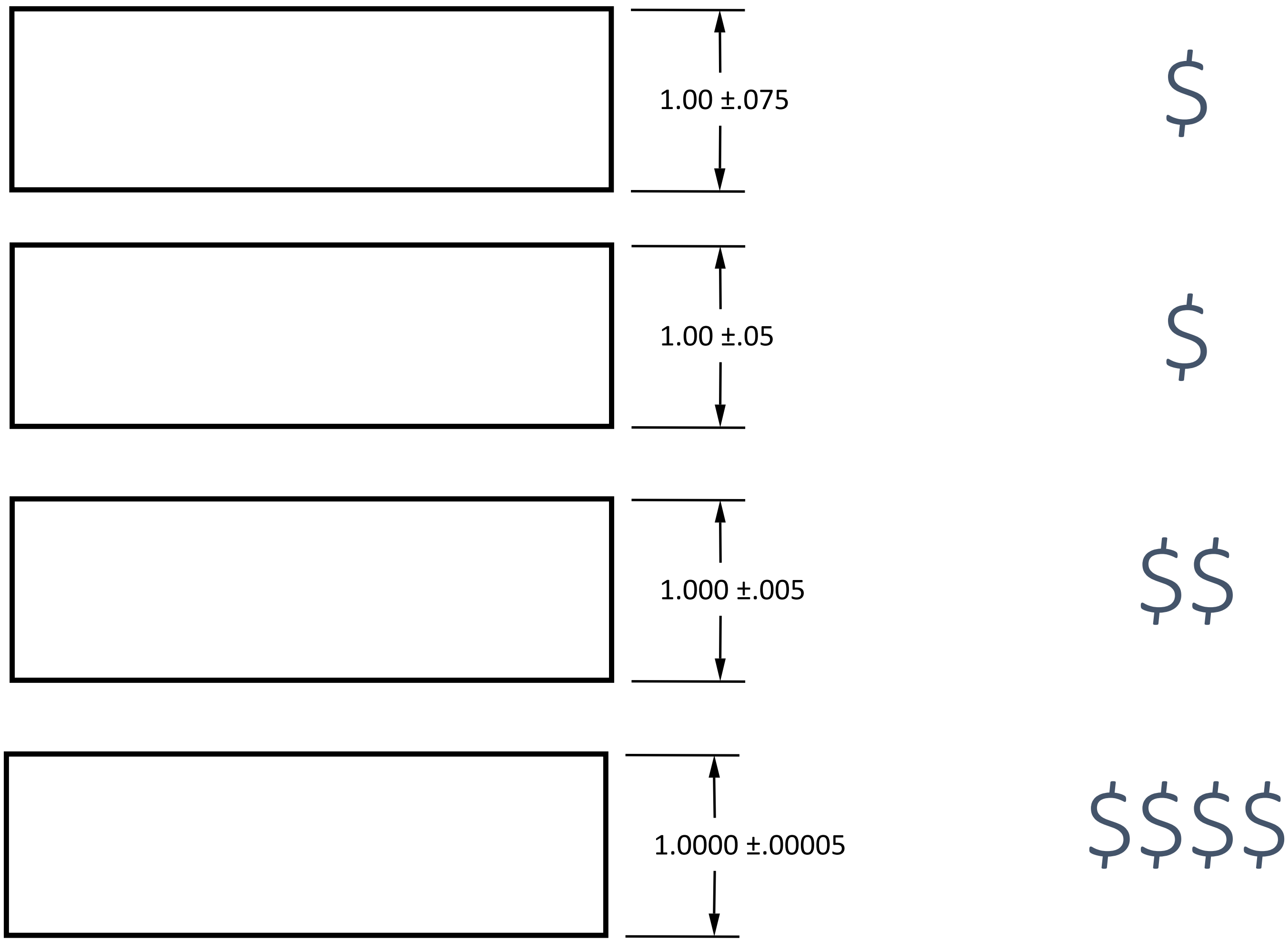
Design Detail

Bent aluminum sheet, 1/16" thick

A or B: Which is more expensive and why?

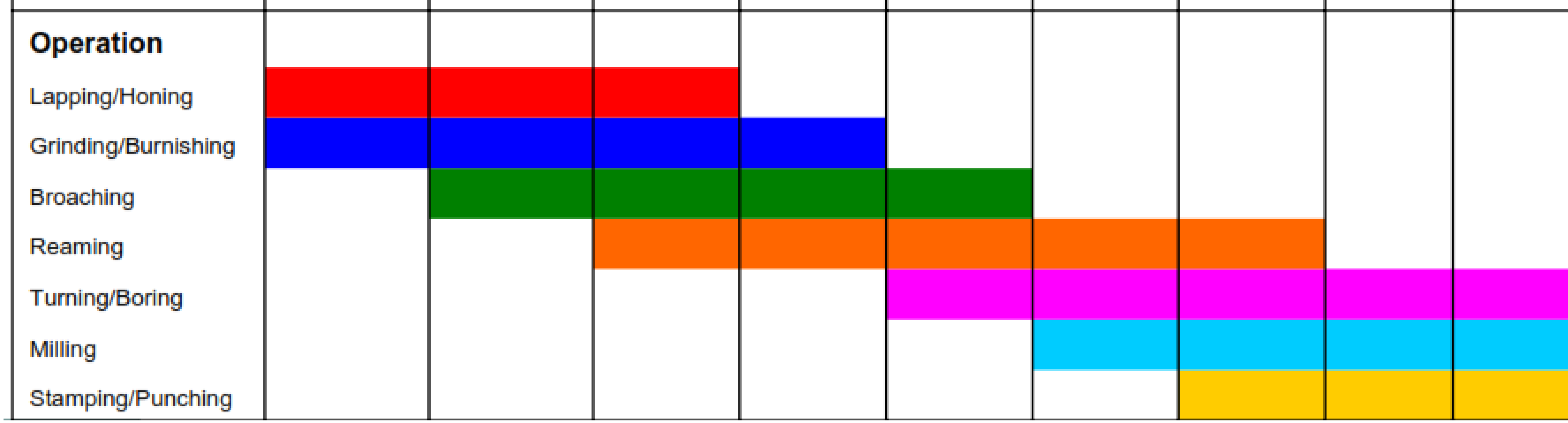


Tolerance vs. Cost



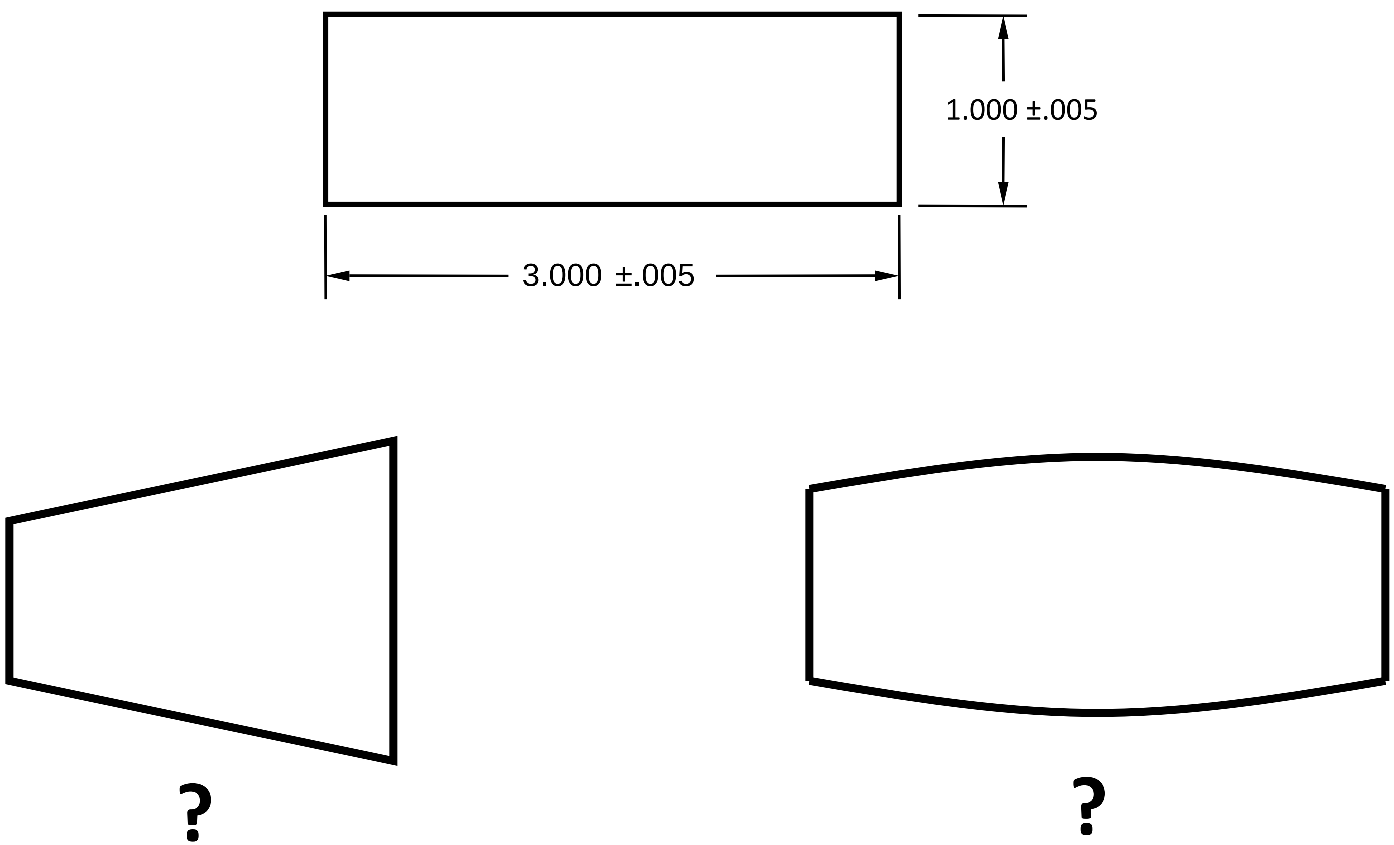
Manufacturing Tolerances

Size (in.)	Total Tolerance (in.)								
0.000-0.599	0.00015	0.0002	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005
0.600-0.999	0.00015	0.00025	0.0004	0.0006	0.001	0.0015	0.0025	0.001	0.006
1.000-1.499	0.0002	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008
1.500-2.799	0.00025	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.010
2.800-4.499	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.012
4.500-7.799	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.010	0.015
7.800-13.599	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.012	0.025

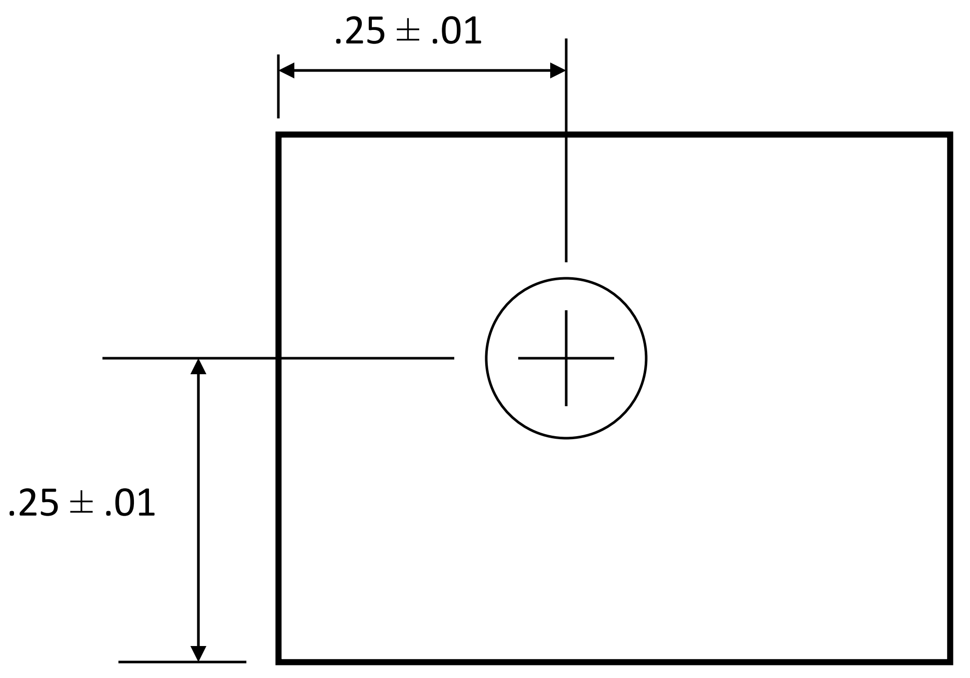


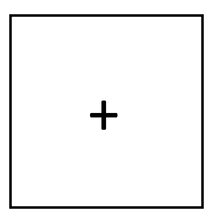
Geometric Dimensioning and Tolerancing (GD&T)

Traditional tolerancing is ambiguous

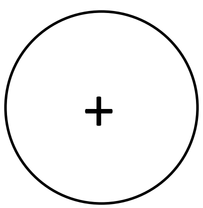


Ambiguity…



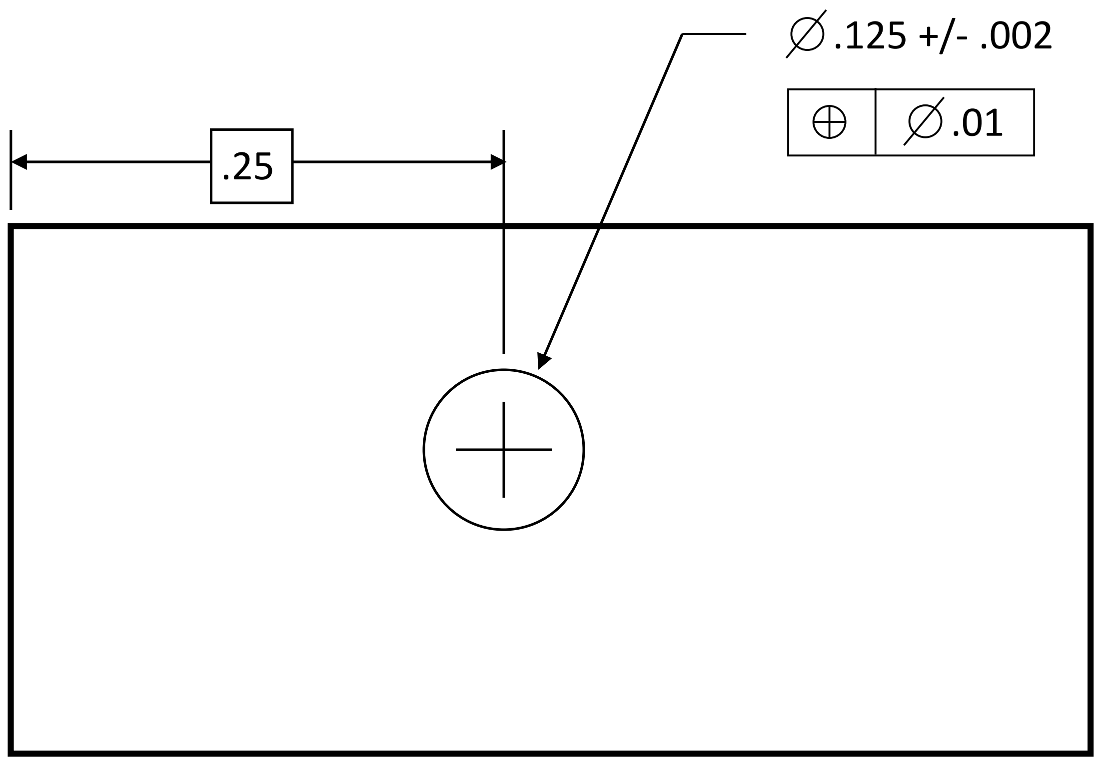


Square deviation



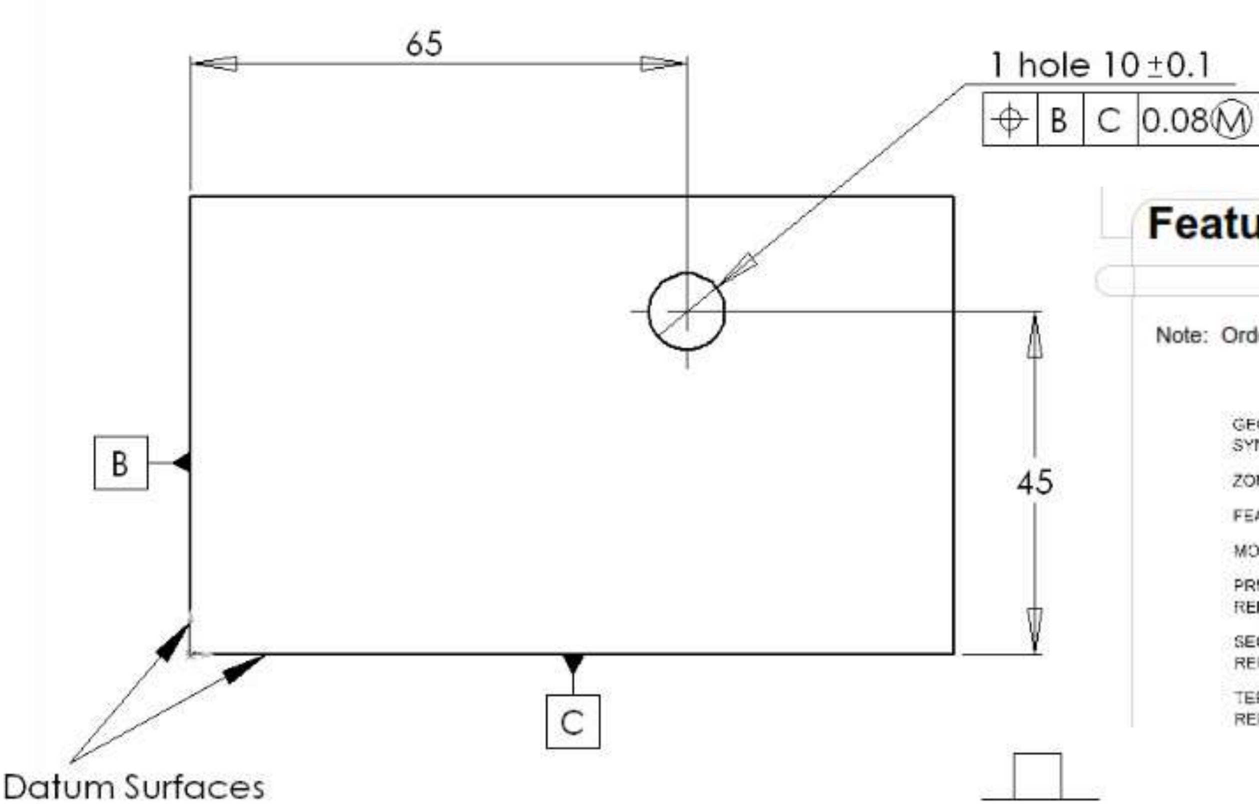
Circular deviation

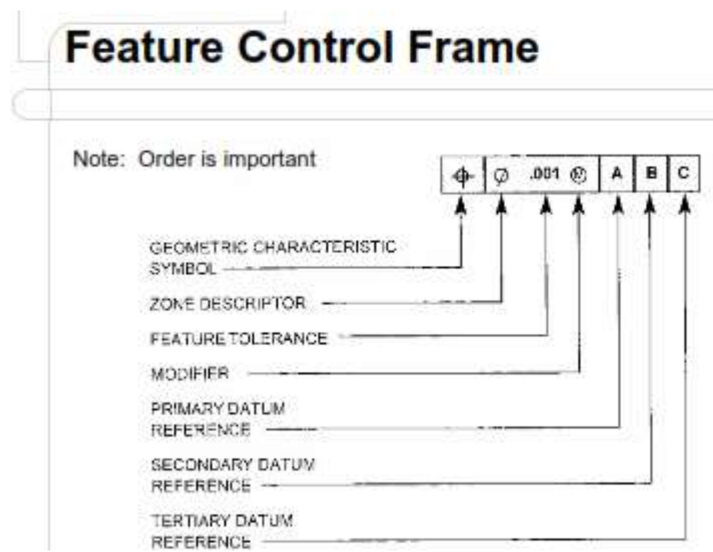
Geometric Dimensioning and Tolerancing



- Ideal position of hole. .25, is marked with box and no +/- notation.
- Feature control box shows how close hole is to exact; within circular tolerance zone with diameter .01

Geometric Dimensioning and Tolerancing





GD&T Resources

	TYPE OF TOLERANCE	CHARACTERISTIC	SYMBOL
FOR INDIVIDUAL FEATURES	FORM	STRAIGHTNESS	⏤
		FLATNESS	⏥
		CIRCULARITY (ROUNDNESS)	○
		CYLINDRICITY	⌭
FOR INDIVIDUAL OR RELATED FEATURES	PROFILE	PROFILE OF A LINE	⌒
		PROFILE OF A SURFACE	⌓
FOR RELATED FEATURES	ORIENTATION	ANGULARITY	∠
		PERPENDICULARITY	⊥
		PARALLELISM	//
	LOCATION	POSITION	⌖
		CONCENTRICITY	◎
	RUNOUT	CIRCULAR RUNOUT	↗*
		TOTAL RUNOUT	⌰*

ME2011 website:

https://sites.google.com/a/umn.edu/me2011/resources

- Efunda tutorial:

http://www.efunda.com/designstandards/gdt

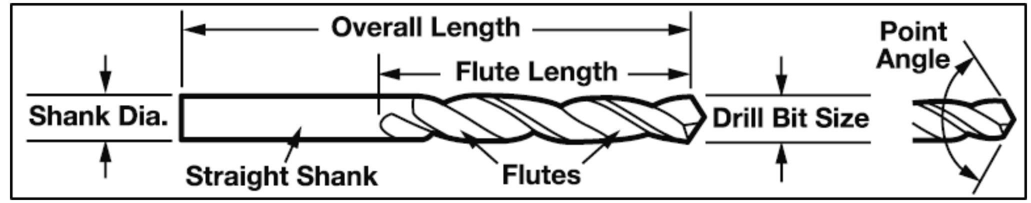
Threaded Fasteners

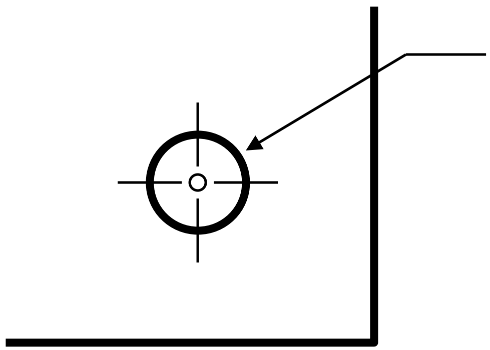
What they are and how to indicate on a drawing

Threaded Fasteners

- Holes
- Threads
- Threaded fasteners

Holes

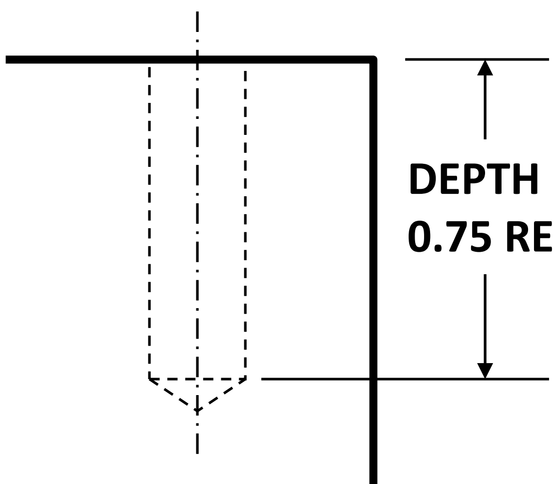




19 DRILL – 0.75 DEEP

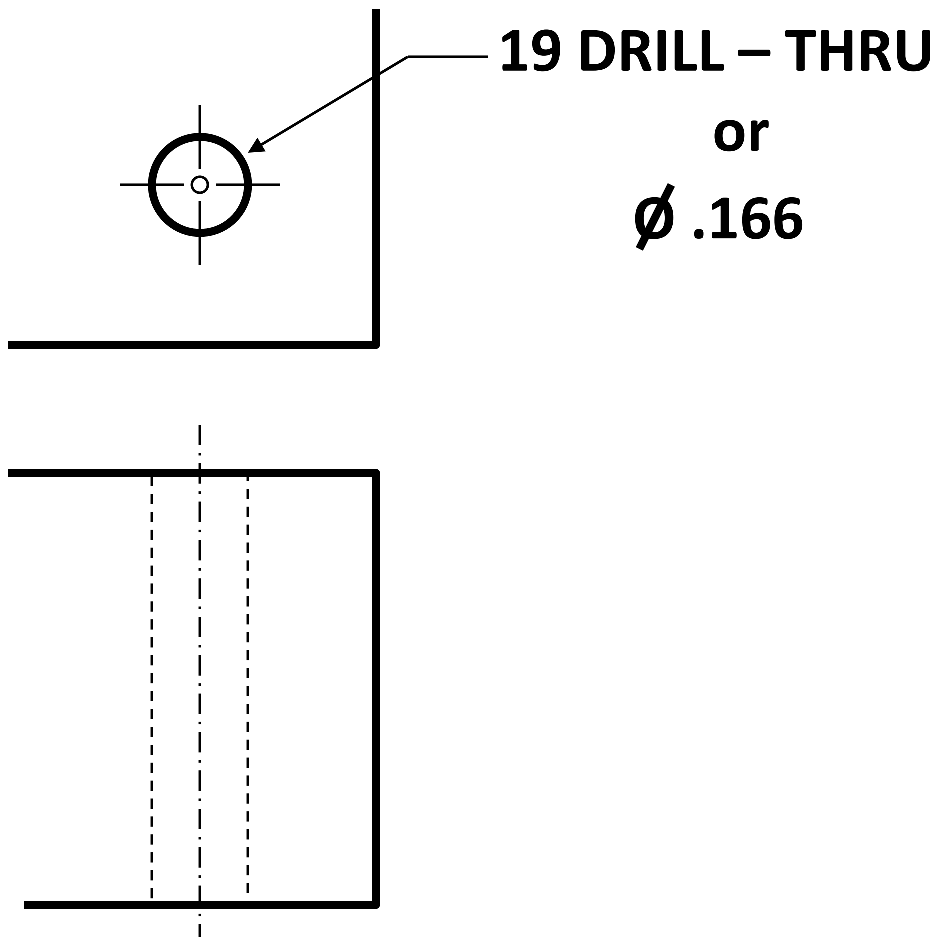
or

Ø .166 ↧ . 75

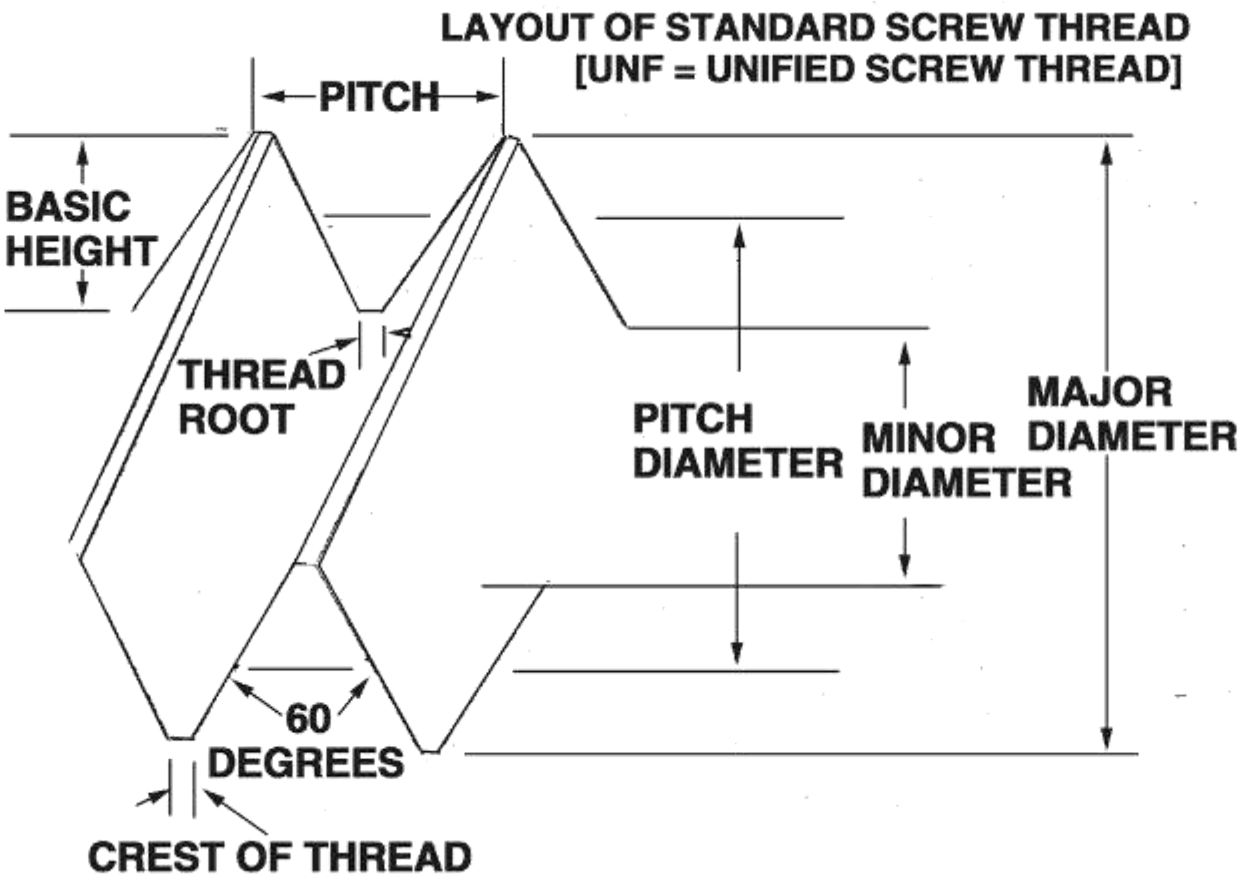


Pix from www.mcmaster.com unless noted

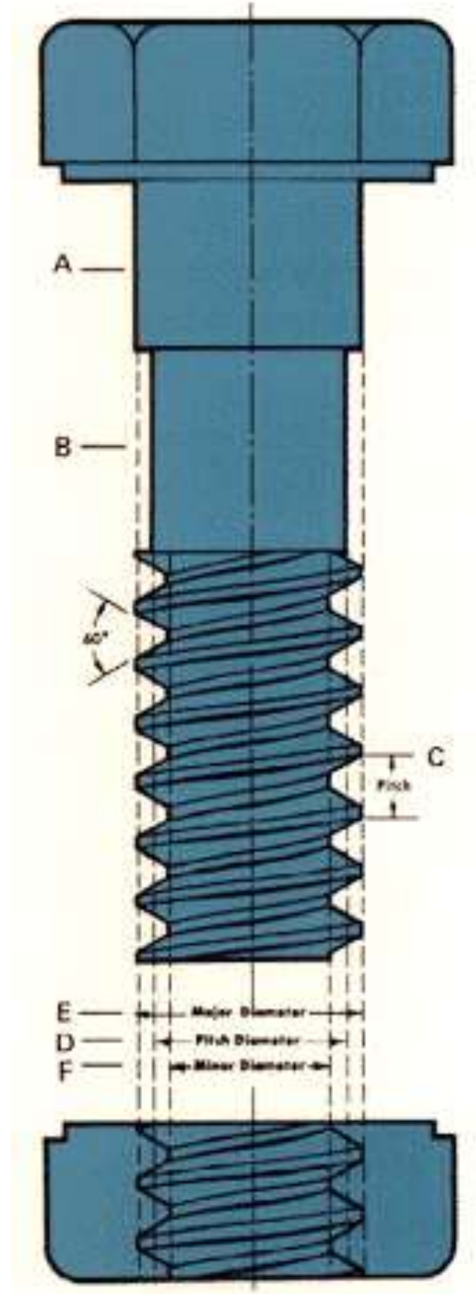
Thru holes



Threads



http://www.machinist.org/harvard_cotreau/mshop6.html



http://www.americanfastener.com/technical/thread_terminology.asp

Threaded Fasteners (screws, bolts)

- Specify diameter, thread, length, head

1/4-20 x 1, RHMS

1/4" DIA

20 THREADS PER INCH

1" LONG

ROUND HEAD MACHINE SCREW

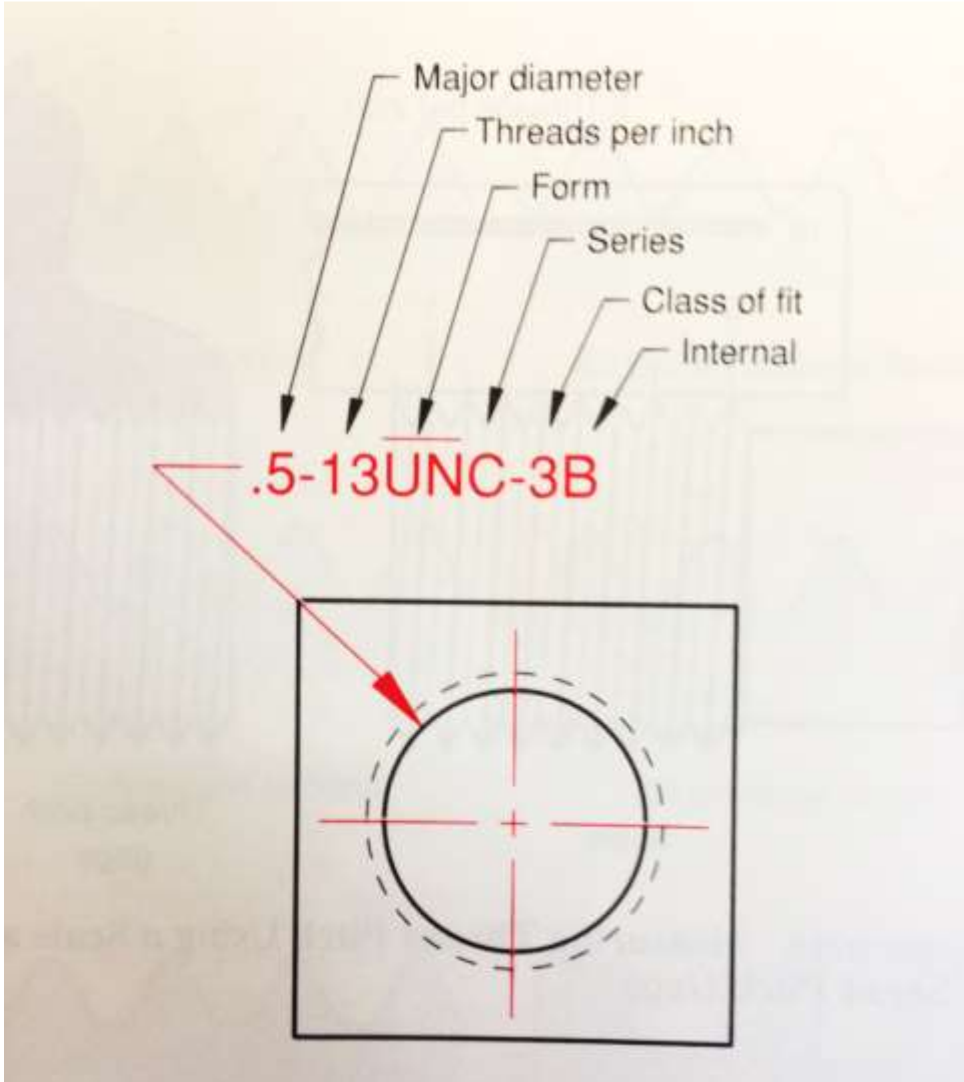
Common screw thread sizes
Unified Thread Standard

- 2-56
- 4-40
- 6-32
- 8-32
- 10-24

- 1/4-20
- 3/8-16
- 1/2-13
- 5/8-11
- 3/4-10

DIA. = (N*.013) + .060 (inches)

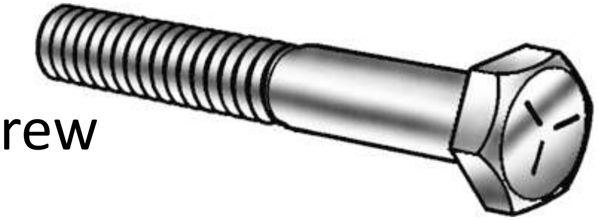
Alternate Thread Callout



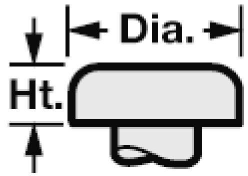
UNC	Means Unified National Coarse
UNF	Means Unified National Fine
UNEF	Means Unified Extra Fine Series
UN	Means Uniform Pitch Series
UNM	Means Unified Miniature Series
NC	Means National Coarse Series
NF	Means National Fine Series
UNR	Means Unified National Round

Head shapes

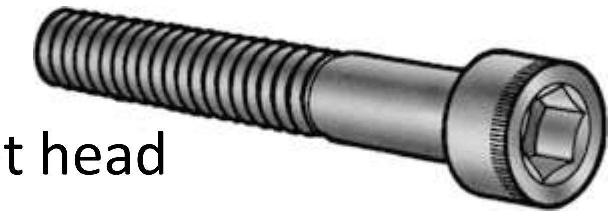
Cap screw



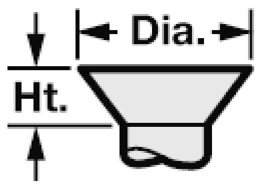
Pan



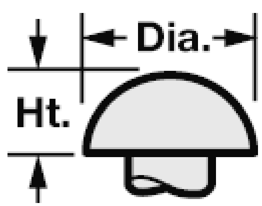
Socket head cap screw (SHCS)



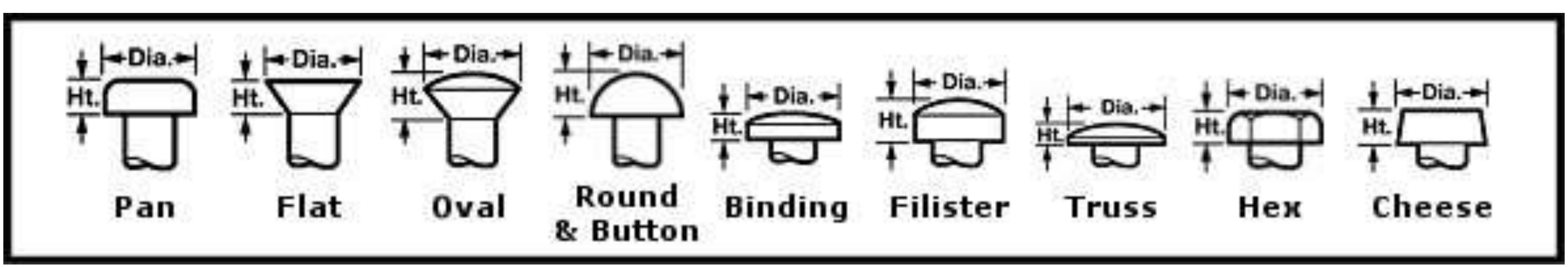
Flat



Round



Set screw



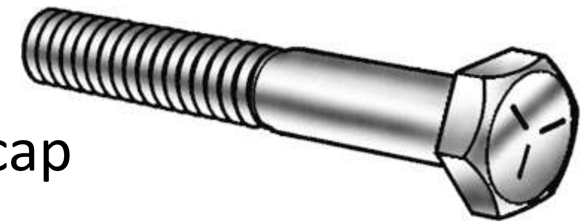
Driving a fastener

Slotted

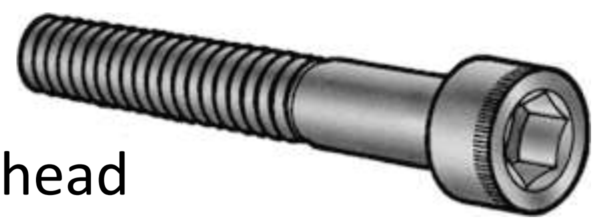
Phillips

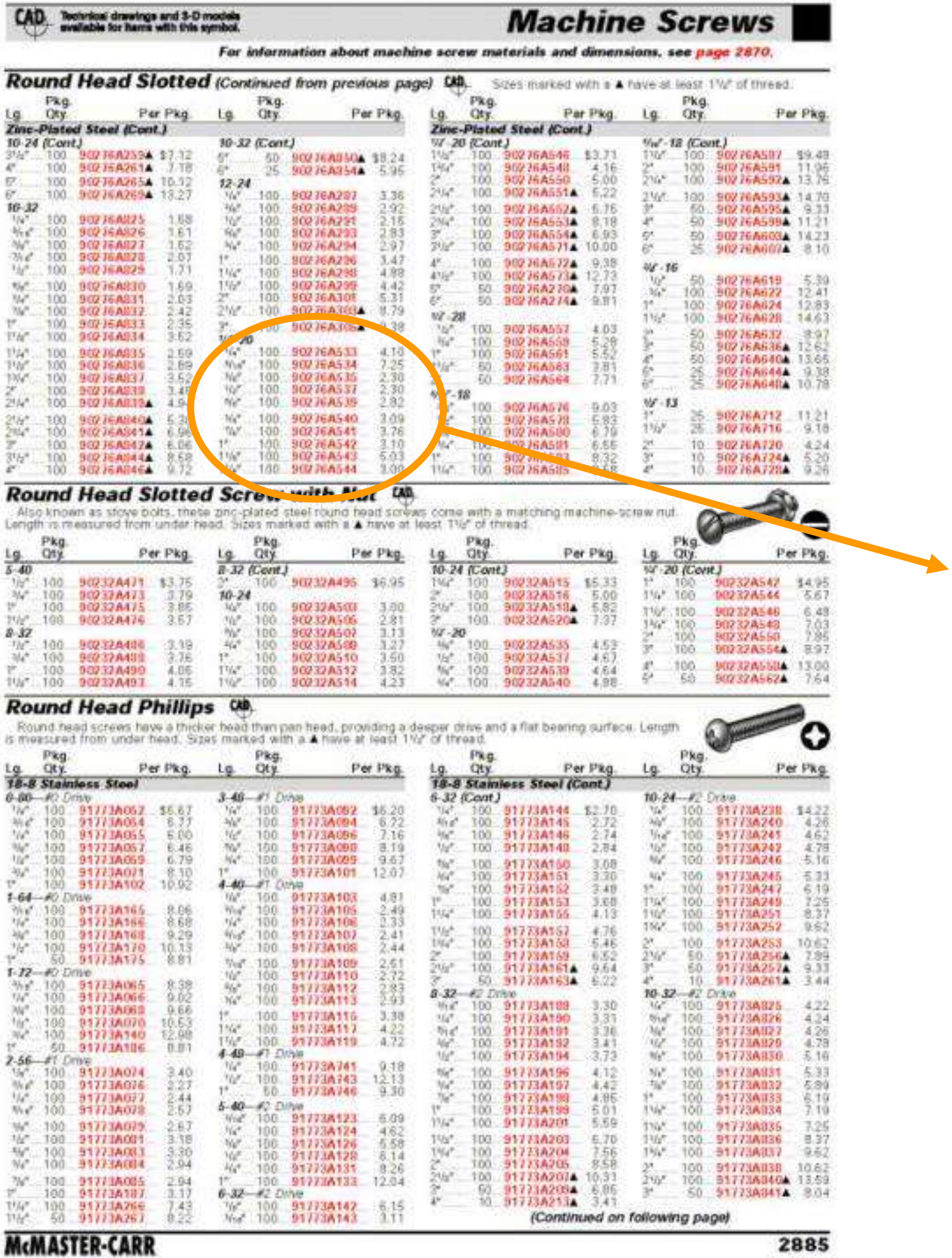
Torx

Hex cap



Hex head
(Allen head)

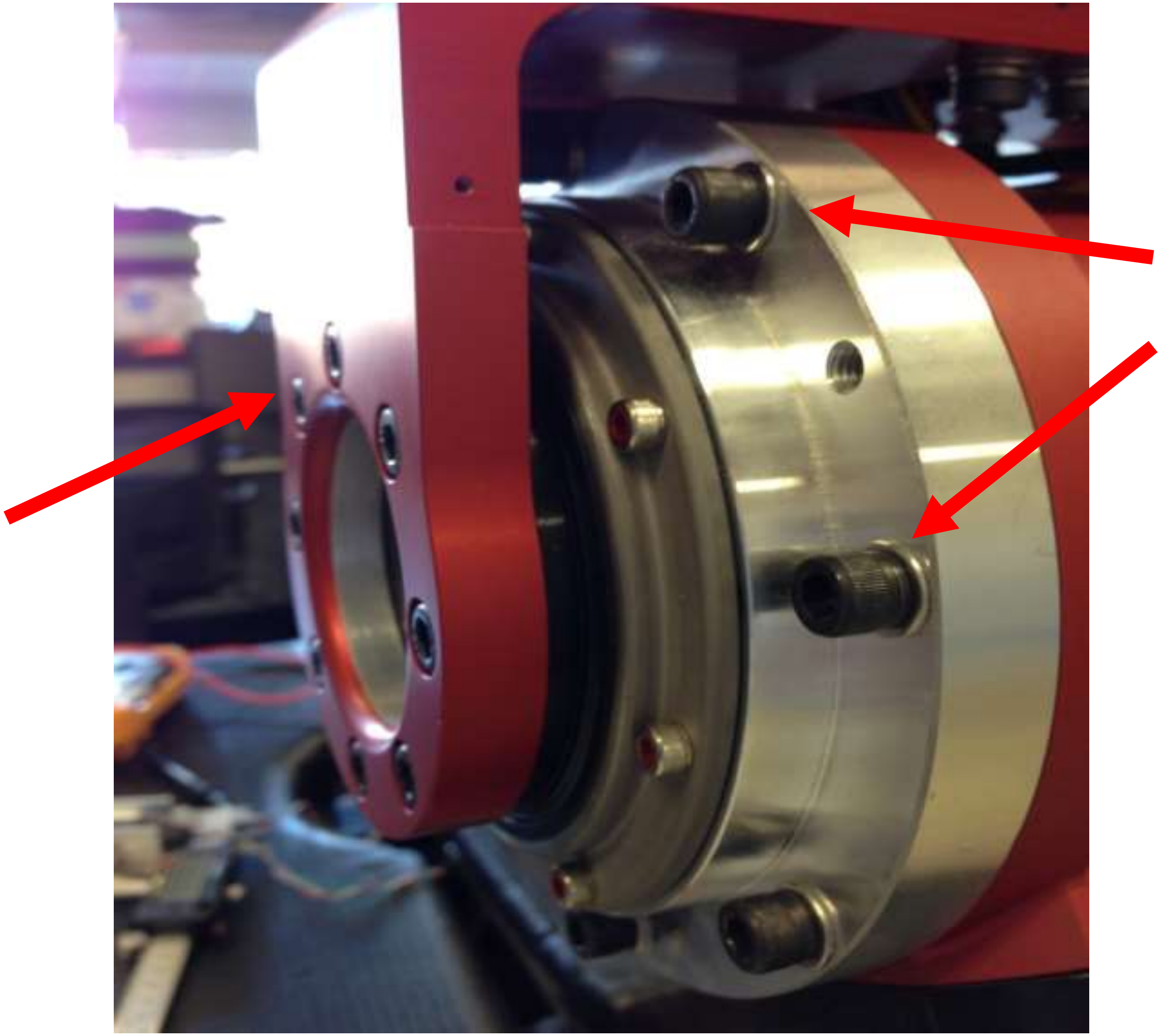




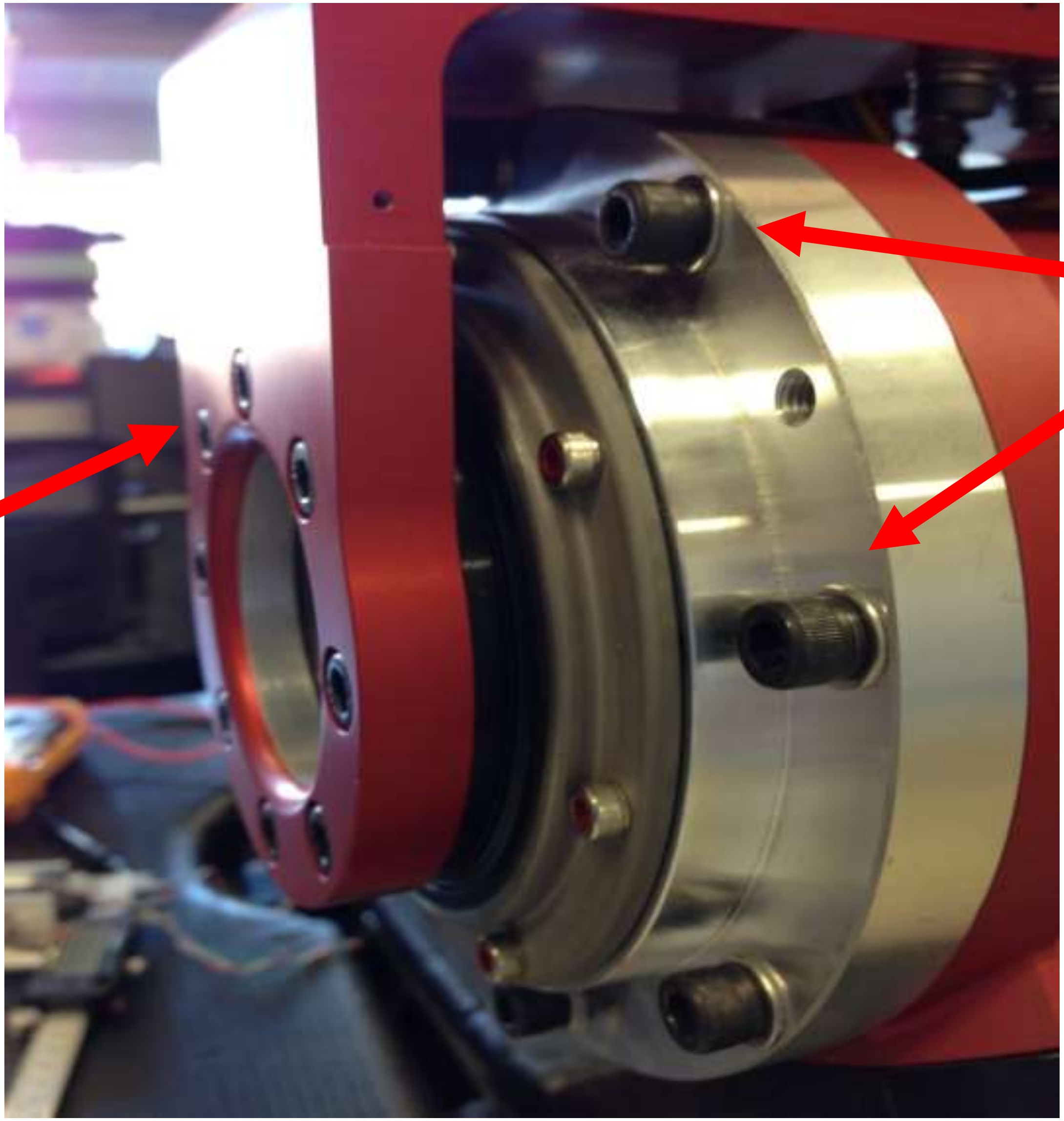
3"	100	90276A305▲	9.38
1/4"-20			
1/4"	100	90276A533	4.10
5/16"	100	90276A534	7.25
3/8"	100	90276A535	2.30
1/2"	100	90276A537	2.30
5/8"	100	90276A539	2.82
3/4"	100	90276A540	3.09
7/8"	100	90276A541	3.76
1"	100	90276A542	3.10
1 1/8"	100	90276A543	5.03
1 1/4"	100	90276A544	3.00

McMaster-Carr
www.mcmaster.com

Name the Fastener:

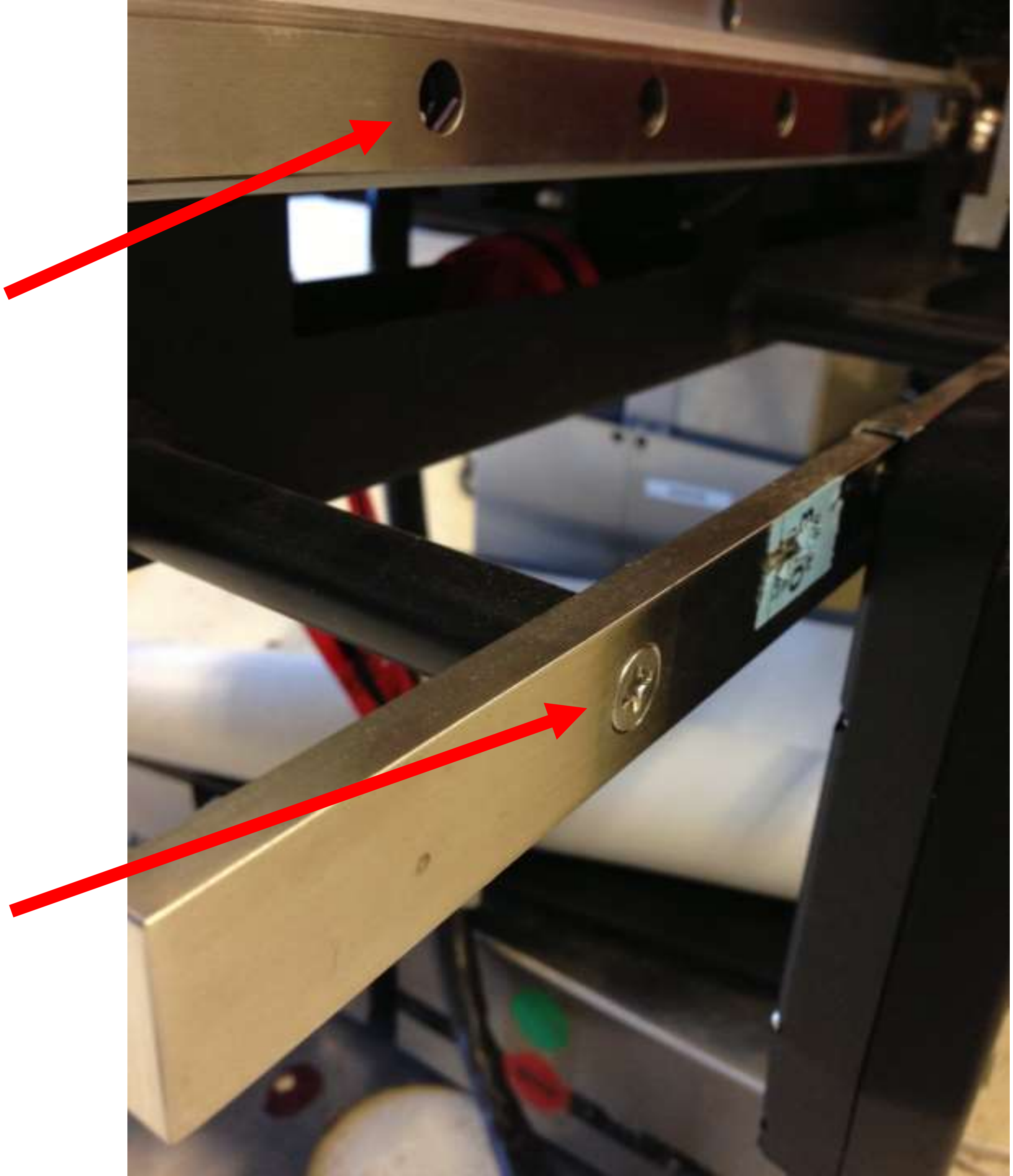


Name the Fastener:

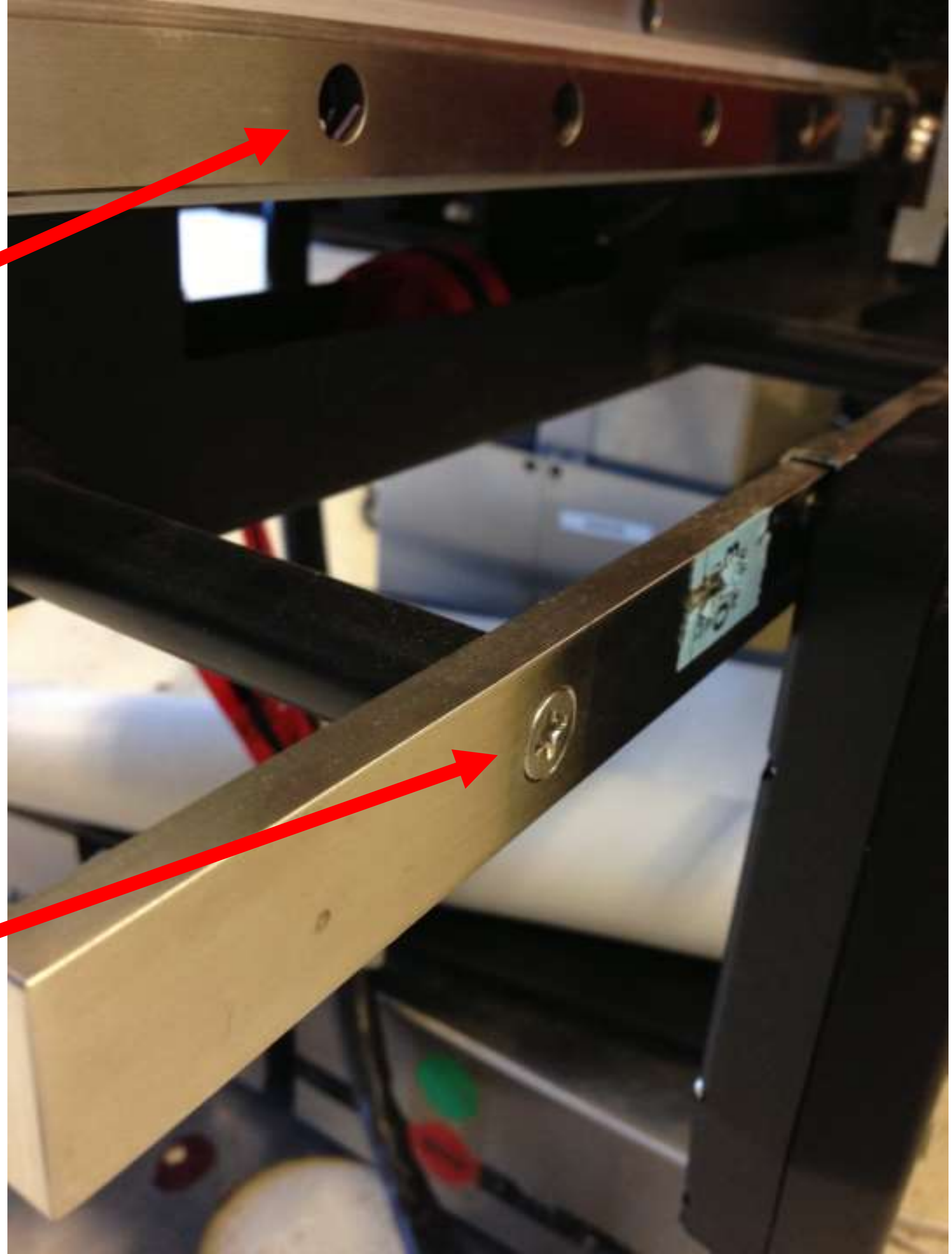


Socket Head
Cap Screw

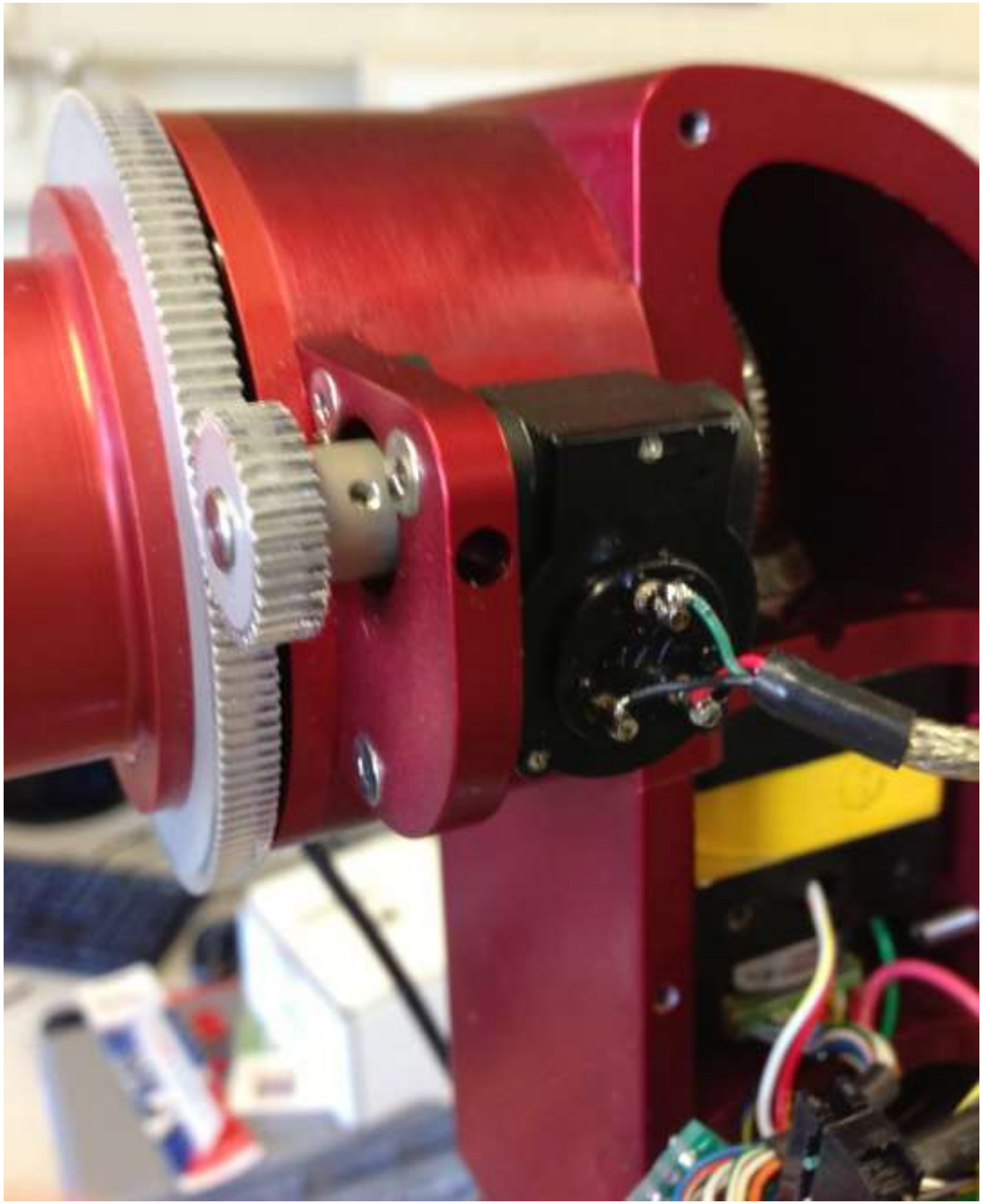
Socket Head
Cap Screw
with counterbore

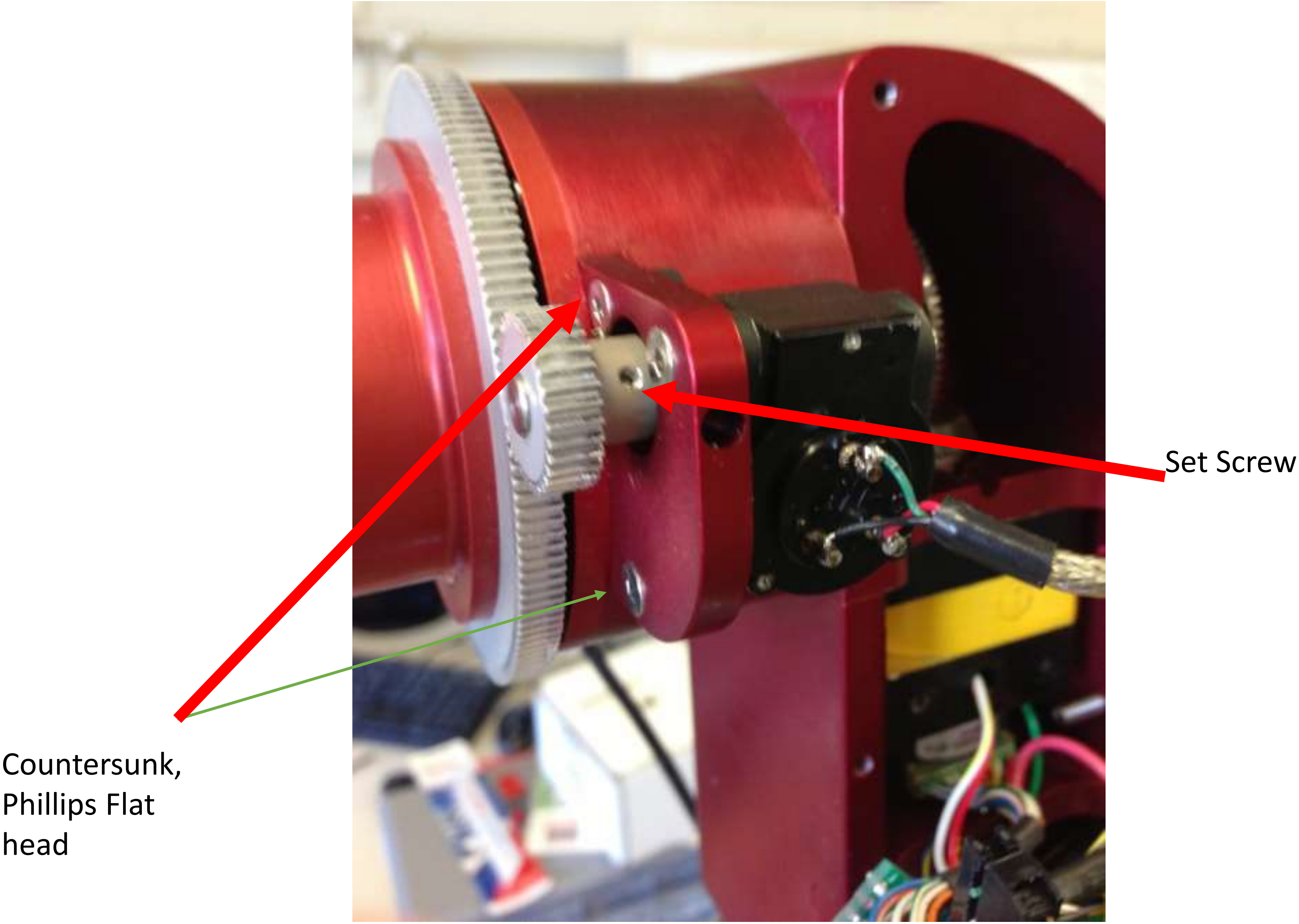


Socket Head Cap Screw with counterbore

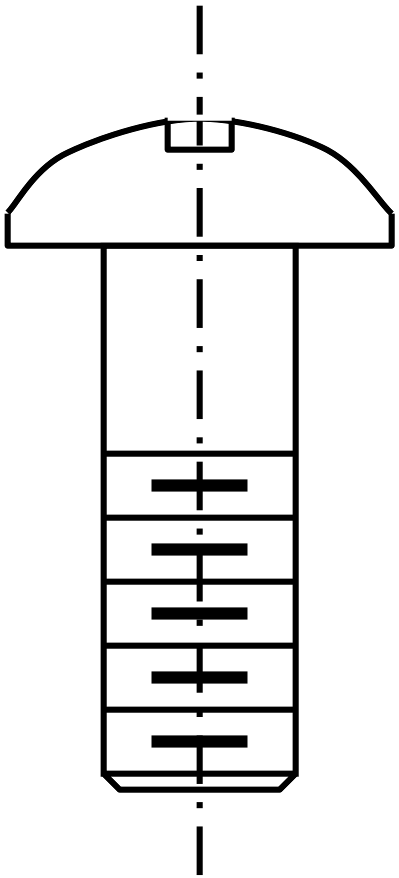


Phillips Flat Head Screw with countersink

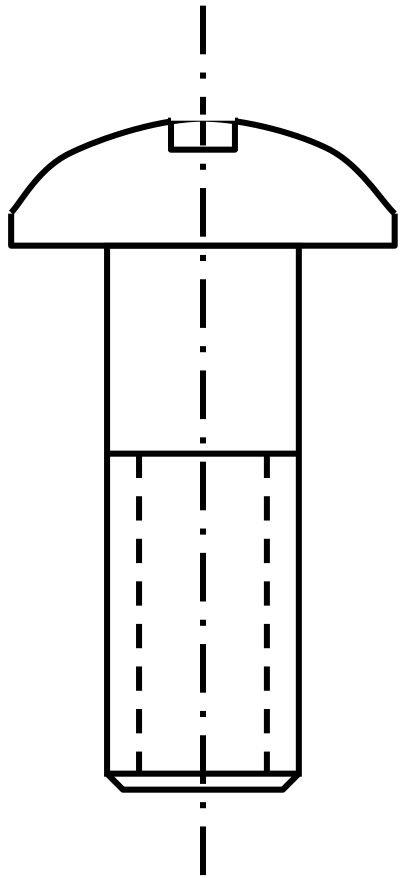



Set Screw
Countersunk,
Phillips Flat
head

Convention for screws

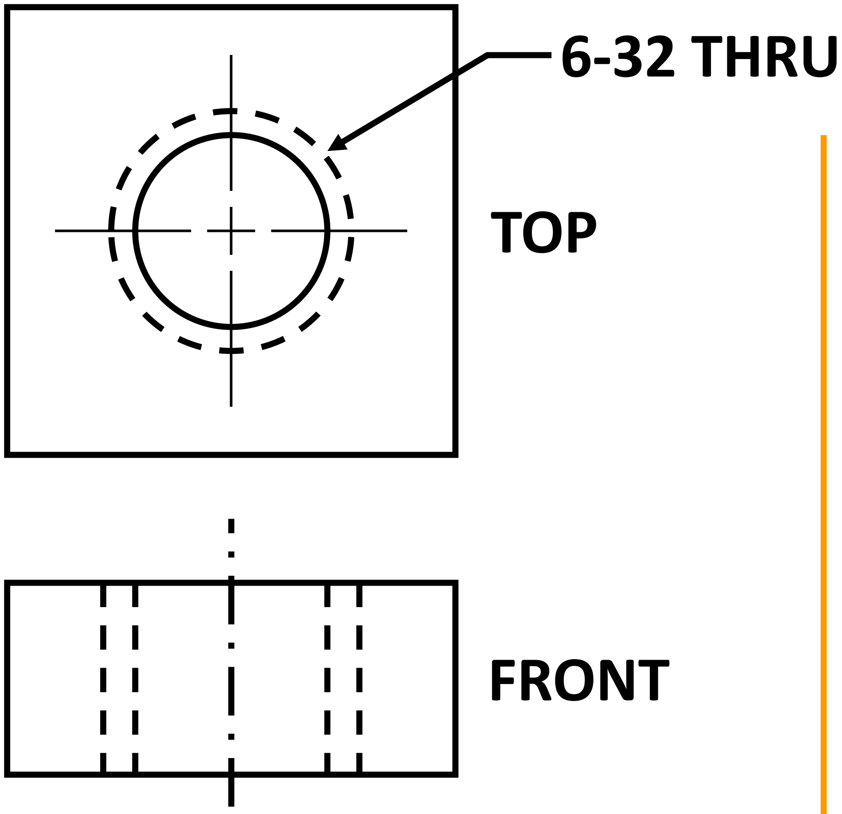


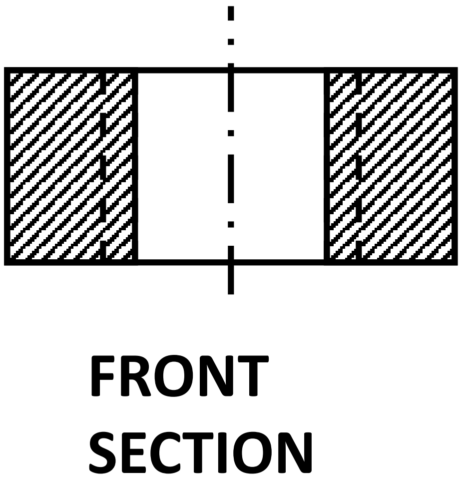
“SCHEMATIC”



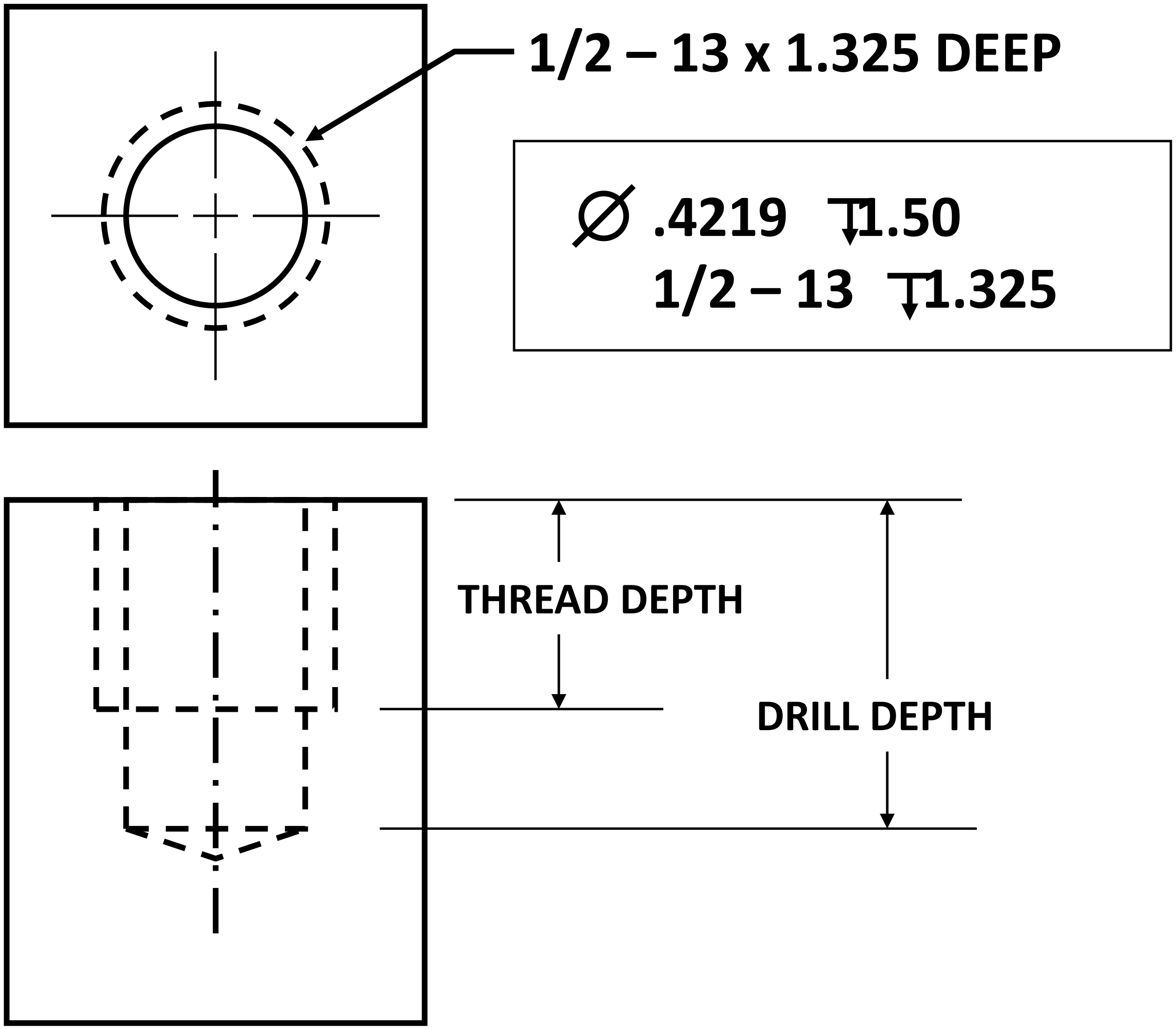
“SIMPLIFIED”

Convention for threaded holes

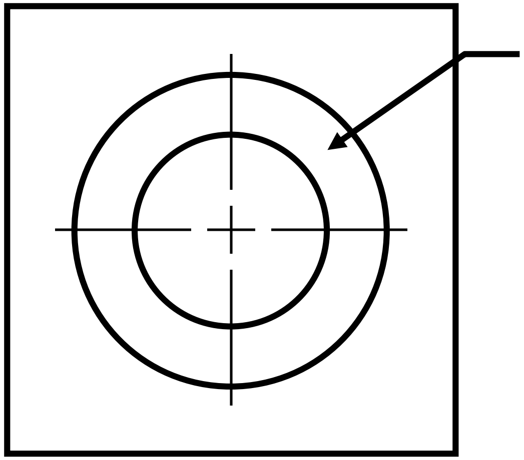




Blind threaded holes

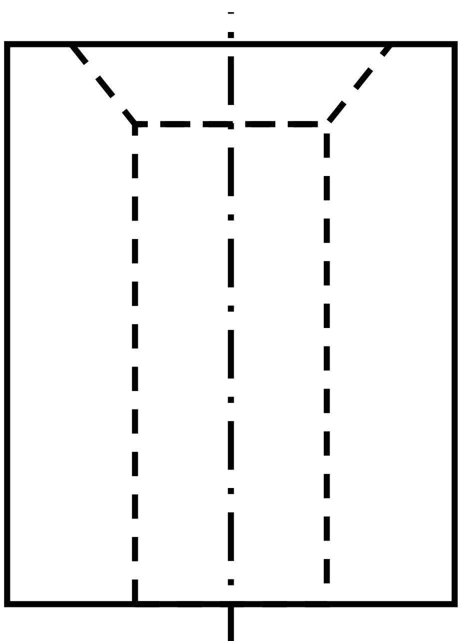


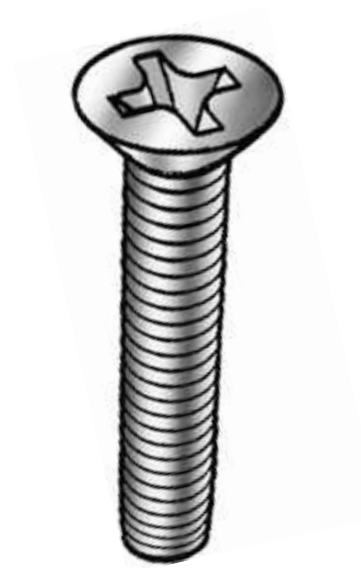
Countersunk holes



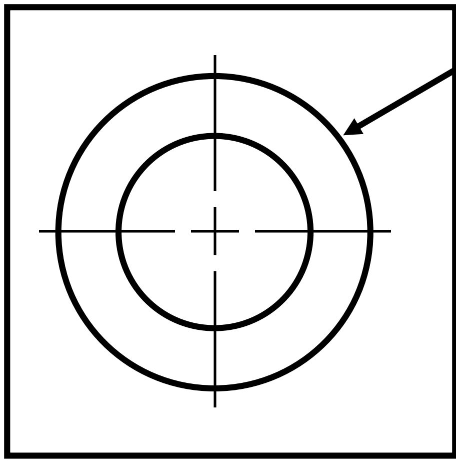
⌀.562 – 82° CSK, 1⌀25

⌀ .562
⌵ ⌀1.125 x 82°





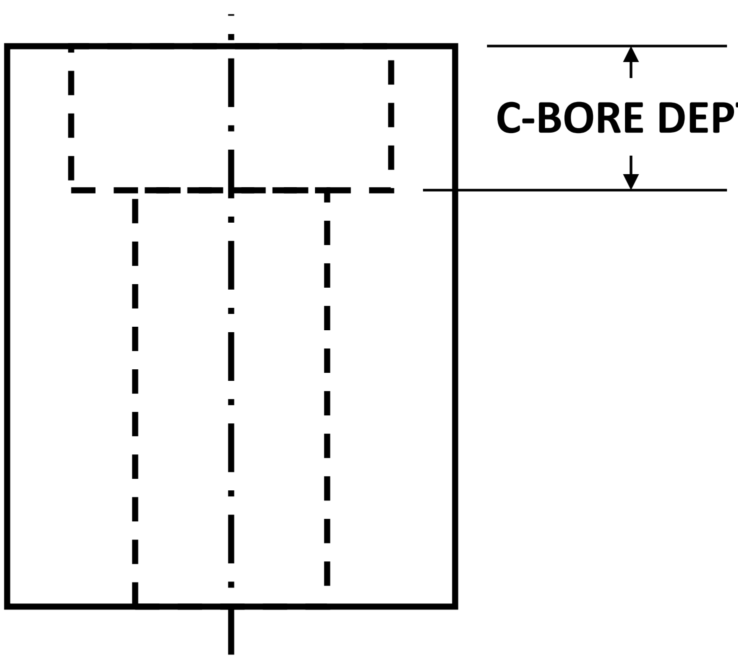
Counterbored holes

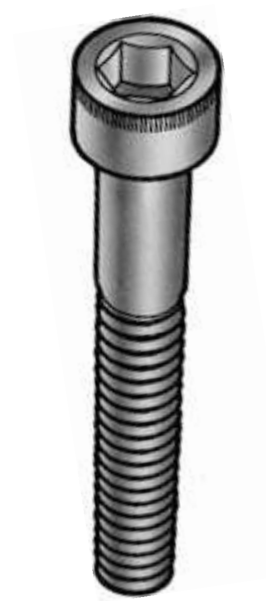


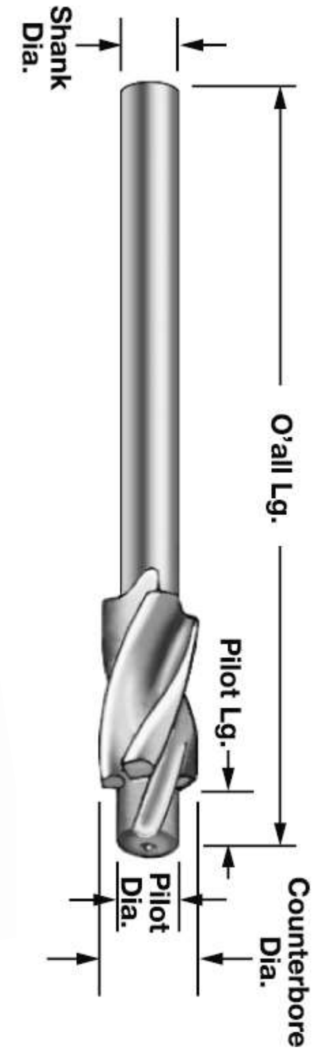
19 DRILL – 29 CBORE, 14 DEEP

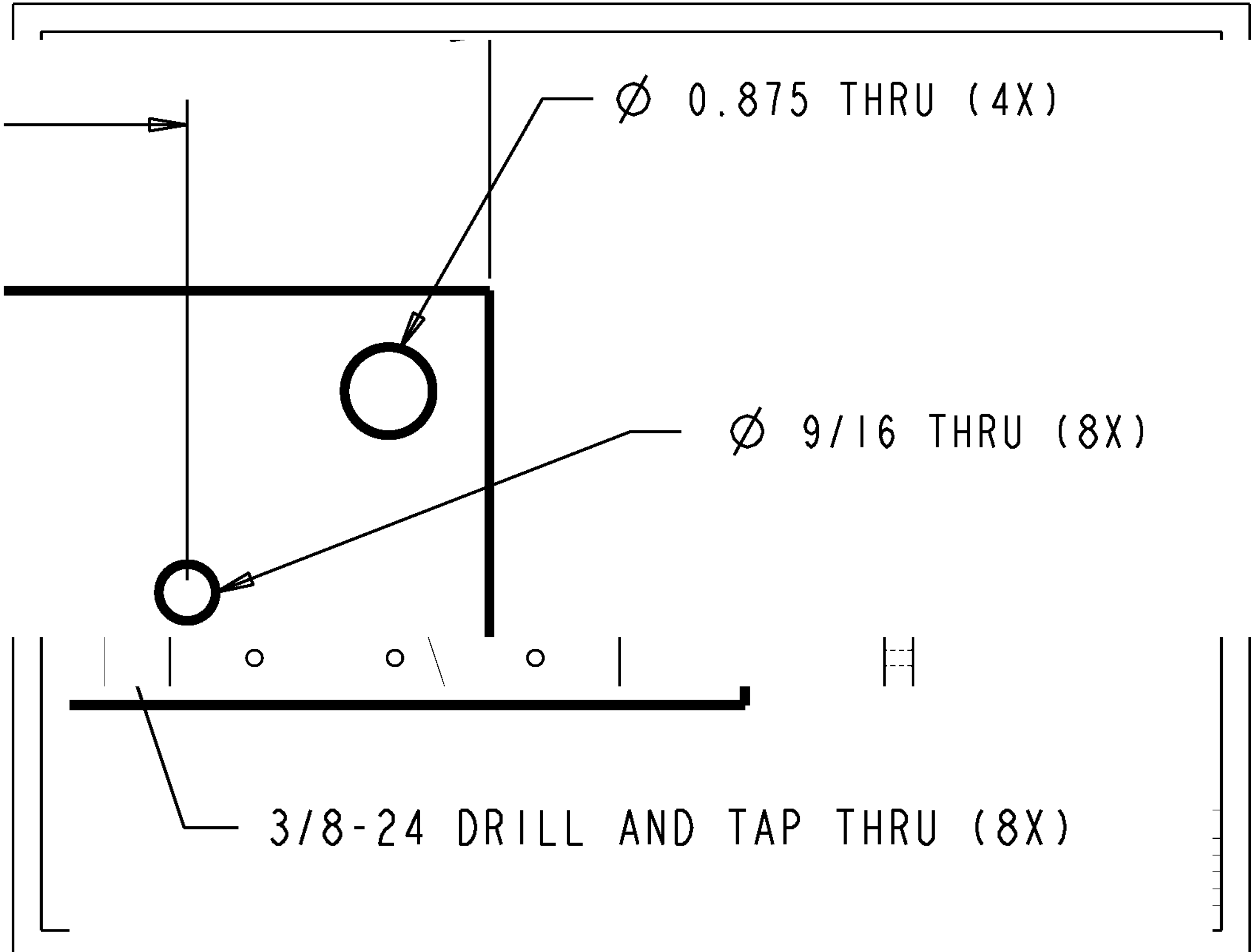
⌀ 19

⌴ ⌀ 29 ↧14



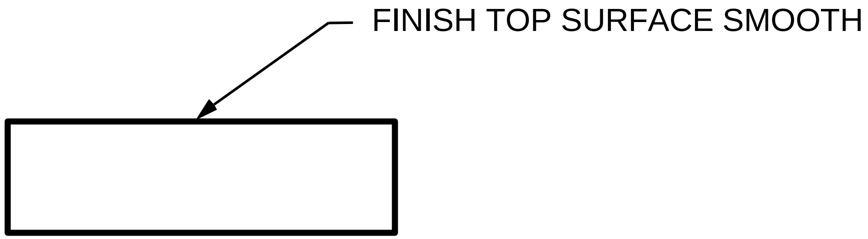


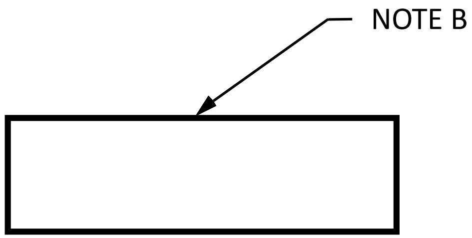



Ø 0.875 THRU (4X)
Ø 9/16 THRU (8X)
3/8-24 DRILL AND TAP THRU (8X)

Other Items for Drawings

Leaders & notes





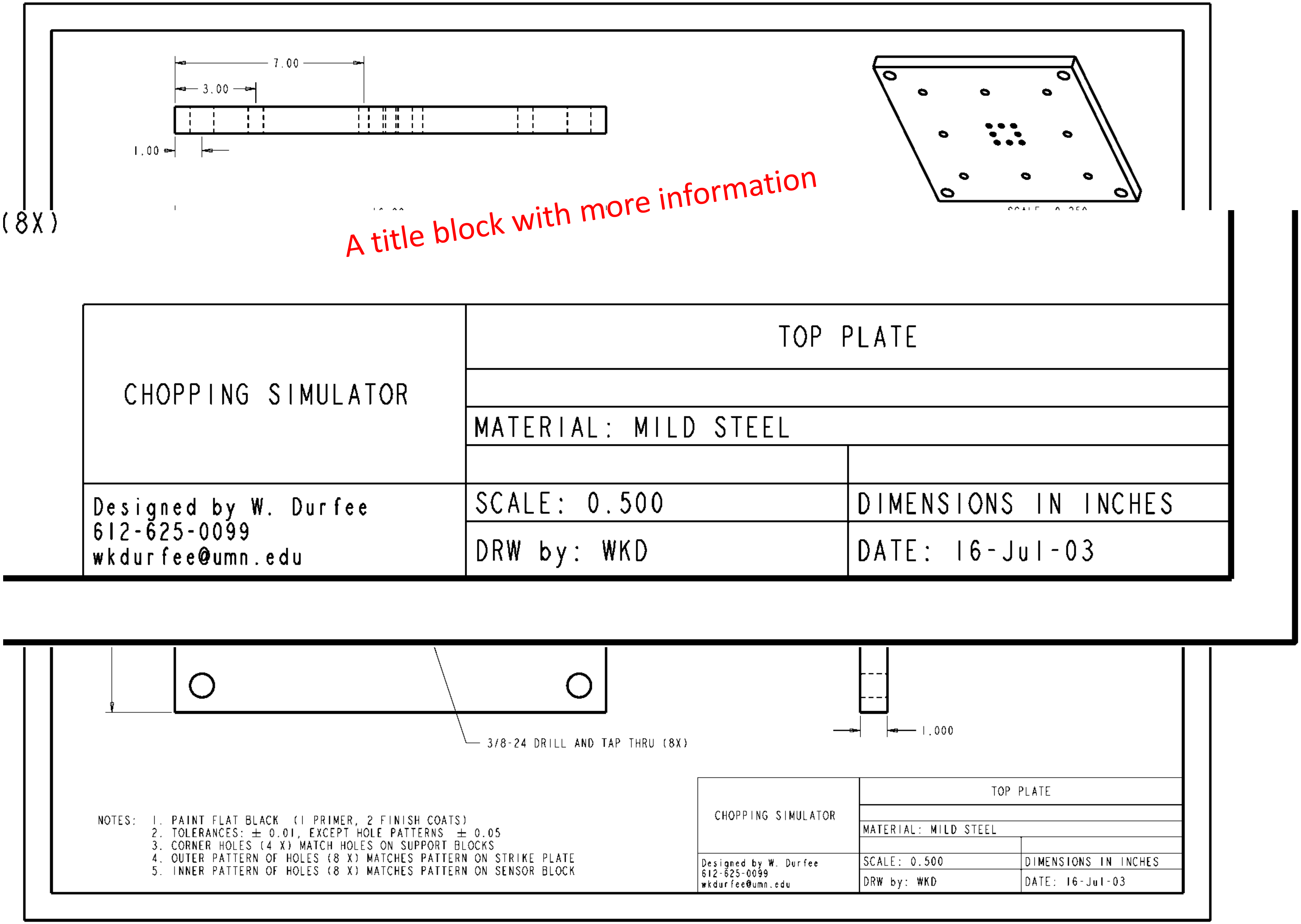
TITLE BLOCKS

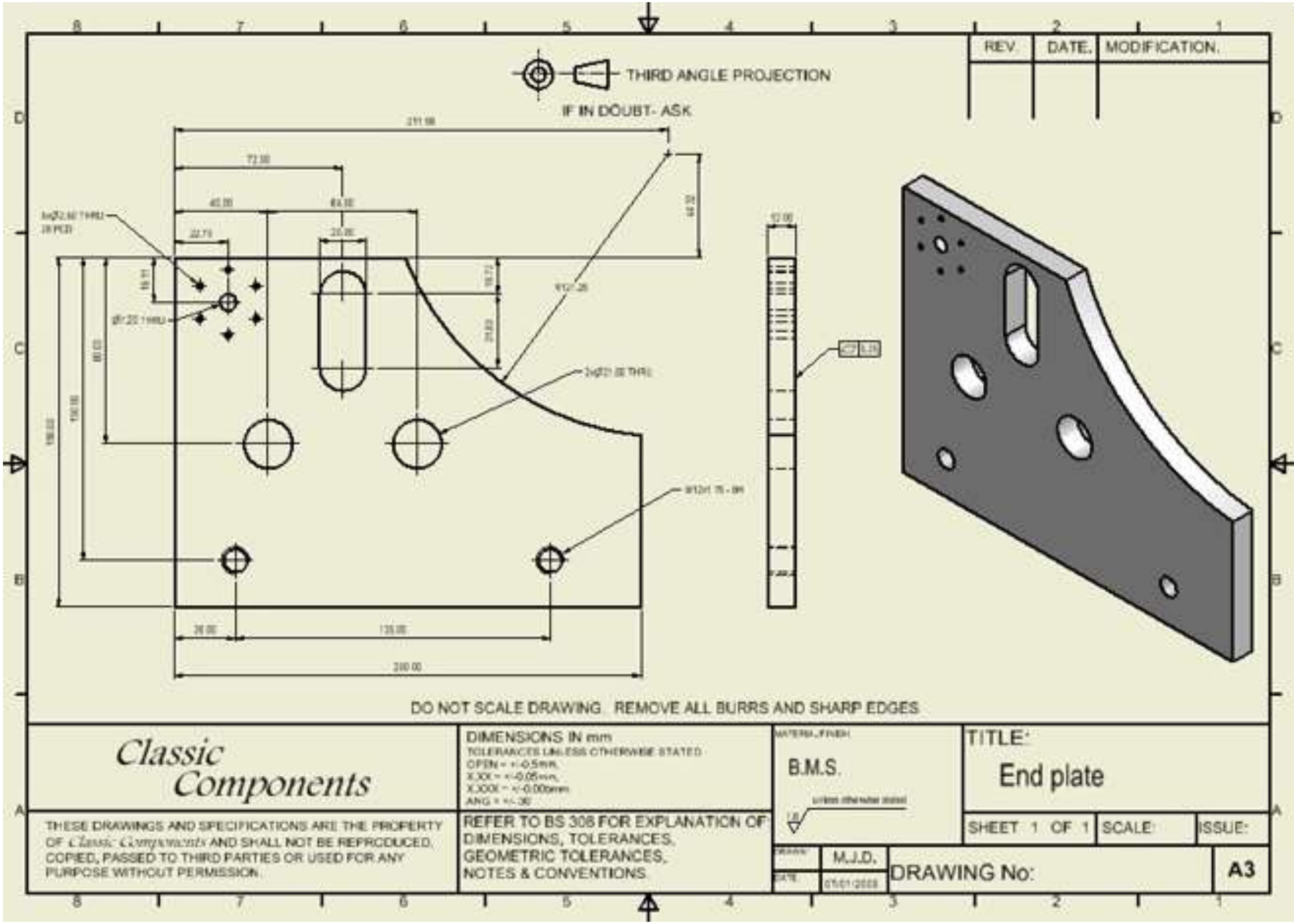
- Basic
  - Title
  - Name
  - Date
  - Units
- Optional
  - Company name, sheet number, scale, tolerances, material, finish....
- Follow your company standards

A basic title block

MY PART	
W. DURFEE	**10/2/2014**
ALL DIMENSIONS IN INCHES	

A title block with more information





A title block using a company template

www.classic-components.co.uk

Production Drawings

Many types of drawings can be produced from the CAD database