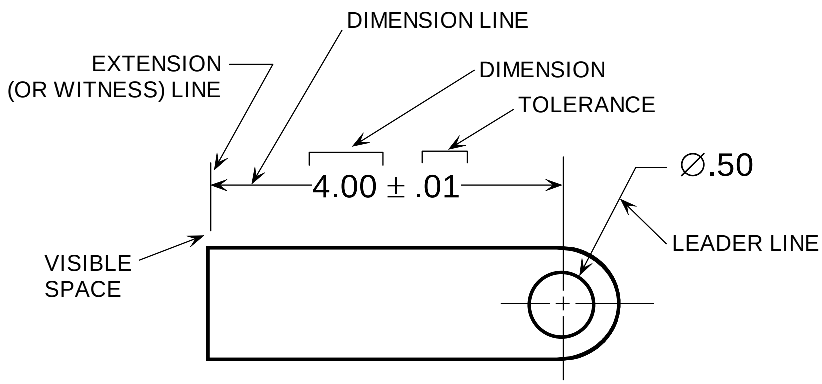
Engineering Drawing (E 122)
Engineering Graphics (E 125)
LECTURE NOTES

12 TOLERANCING & ASSEMBLIES

I. Prelims – (CT brings – calipers), last time (machining basics, dimension layout & rules) (2h)

II. Tolerancing basics



A. What is it?
   1. Tolerances specify acceptable __________ in the _________ of a part.
   2. “Tolerance” is the _____ amount a given _________ is permitted to ____.

B. Why are there tolerances?
   1. ____________________________!
   2. ____!

C. A brief history – improving manufacturability
   1. Before – manufacture 2 different ______ parts, pin A and block with hole B. You want pin A to fit into hole B, but some pins fit and others don’t.
   2. So what do you do? You “_____” them based on individual sizes. You measure ALL of the pins and ALL the holes and you _________ them (place them into “bins”, maybe labeled: “big”, “medium”, and “small”). Then you match big-holed parts with the big pins, and also small-holed parts with small pins. This way you never run into the situation where a big pin is matched with a small hole, and it doesn’t fit.

D. “_______________” parts. Control the manufacturing process well enough so that _____ part A (that meets specifications) will fit with _____ part B (that meets specifications). Now you no longer have to _____ parts individually.

E. Basic rules of tolerancing
   1. _____________ should have a tolerance!
   2. Allow _________________ as possible, without sacrificing the “______________________” of your parts.

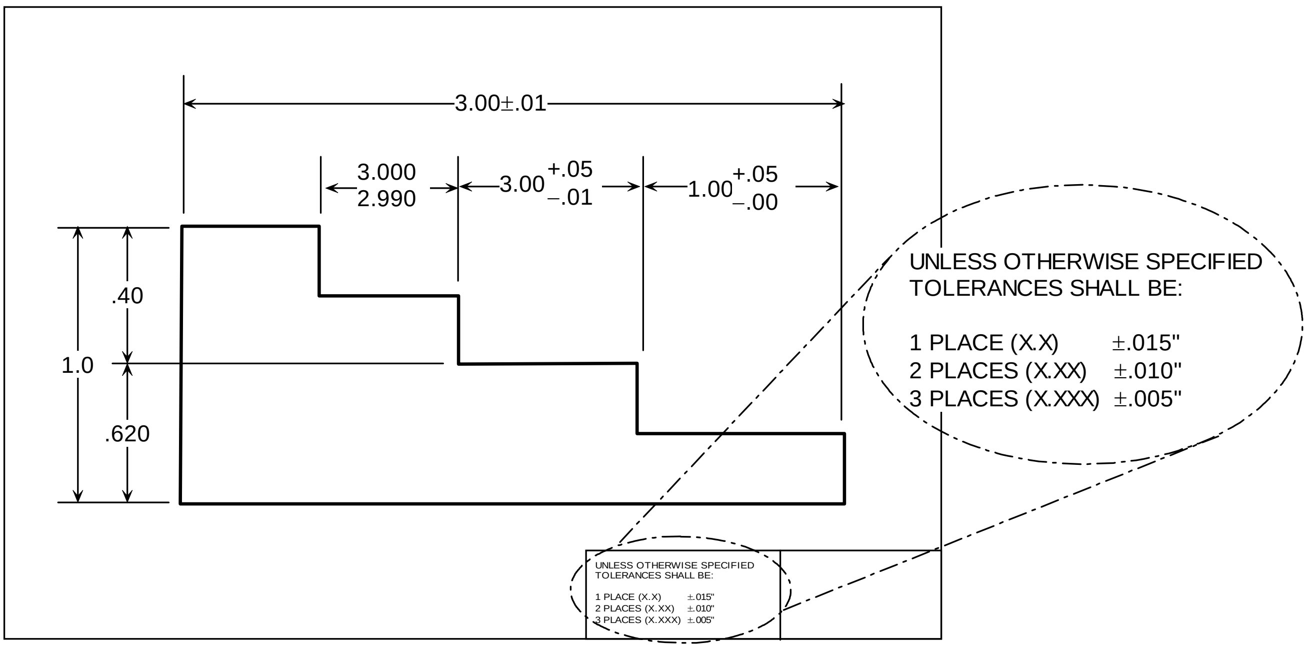
III. Terminology

Consider the dimension: 4.000 ± .005

A. _____ size = ____.
B. Tolerance = .010; the _____ amount that a specific _________ is permitted to ____.

IV. Tolerance Application (how do you apply the tolerance to the drawing?)

A. Direct – tolerance is applied on a ________________.
B. General – tolerance is applied in the __________ (also called "___" or "_______" tolerance). These tolerances are implied by the number of ______ specified behind the _______ in the ________.



V. Direct Tolerancing Expressions (or Methods)

A. Plus-minus $4.000 \pm .005$

1. Symmetric _____ ± _____.

2. Bilateral (unequal) – $4.000^{+.005}_{-.003}$

3. Unilateral – $4.000^{+.005}_{-.000}$

B. Limit
4.000
3.995

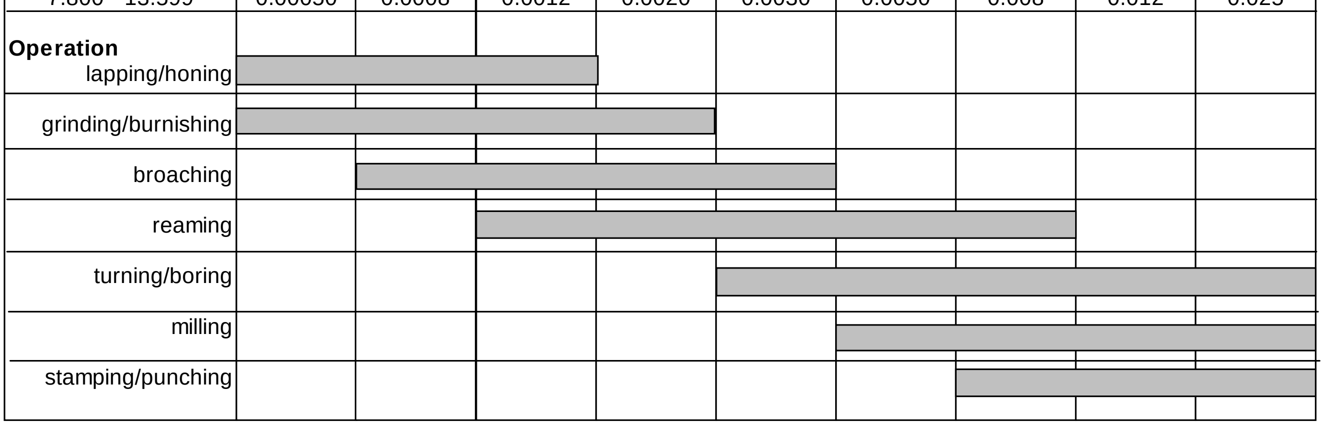
VI. Tolerance and Manufacturing

A. Each manufacturing process (e.g., machining, forging, molding, casting, grinding) is inherently capable of a certain level of ________.
B. Range of tolerances for machining processes

STANDARD TOLERANCE FOR DRILLED HOLES

DRILL SIZE (IN.)	TOLERANCE (IN.) (+)	(–)
.0135 (80) - .185 (13)	.003	.002
.1875 - .246 (D)	.004	.002
.250 - .750	.005	.002
.7656 - 1.000	.007	.003
1.0156 - 2.000	.010	.004
2.0312 - 3.500	.015	.005

PART 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	0.0010	0.0015	0.0025	0.004	0.006
1.000 - 1.499	0.00020	0.0003	0.0005	0.0008	0.0012	0.0020	0.003	0.005	0.008
1.500 - 2.799	0.00025	0.0004	0.0006	0.0010	0.0015	0.0025	0.004	0.006	0.010
2.800 - 4.499	0.00030	0.0005	0.0008	0.0012	0.0020	0.0030	0.005	0.008	0.012
4.500 - 7.799	0.00040	0.0006	0.0010	0.0015	0.0025	0.0040	0.006	0.010	0.015
7.800 - 13.599	0.00050	0.0008	0.0012	0.0020	0.0030	0.0050	0.008	0.012	0.025



VII. Determining tolerances

A. ______ dimensions – must have a specific _____ in order for proper "______________ ________".

1. Form – part must have correct _____,
2. Fit – part must be able to fit together with other parts in an ________.
3. Function – part must ____.
4. Pick a ______________ process that will ensure this tolerance requirement. I.e., the tolerance drives the manufacturing process.

B. ____________ dimensions – their actual value is not so important. In this case, pick a manufacturing process that is _____ and _________. Then adjust the tolerance value on the drawing that can be easily achieved using this process. (e.g., with milling the best tolerance range is about ___________").

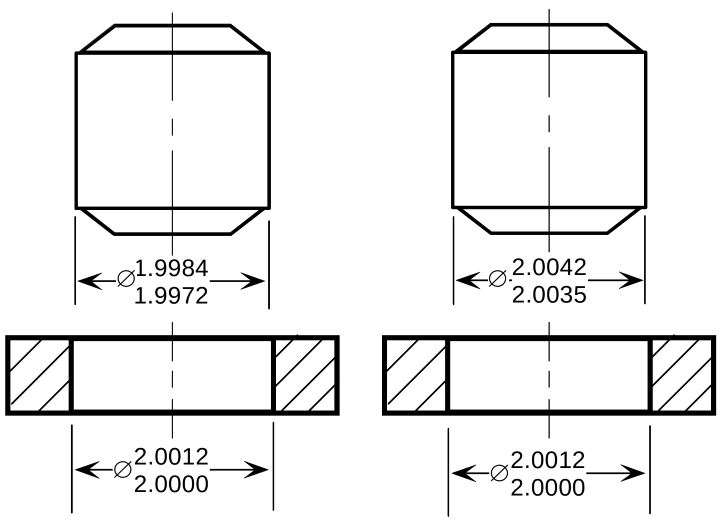
VIII. Fits

A. Fit – the range of _________ resulting from _________ between ______ parts
B. Actual size – the ______ (________) size of a part. A part "_______" (within specifications) or "meets print" has an actual size that falls within the ___________________ range.
C. General Fits

1. Clearance – fit having ______________ so that there is always _________ between mating parts that are in spec.
   a. Pins "in spec" are always smaller than holes "in spec".
   b. Use when 2 parts must ___ together. These parts slip together readily.
   c. Example – a hole of ∅ 4.000 ± .005 and a pin 3.990 ± .005.

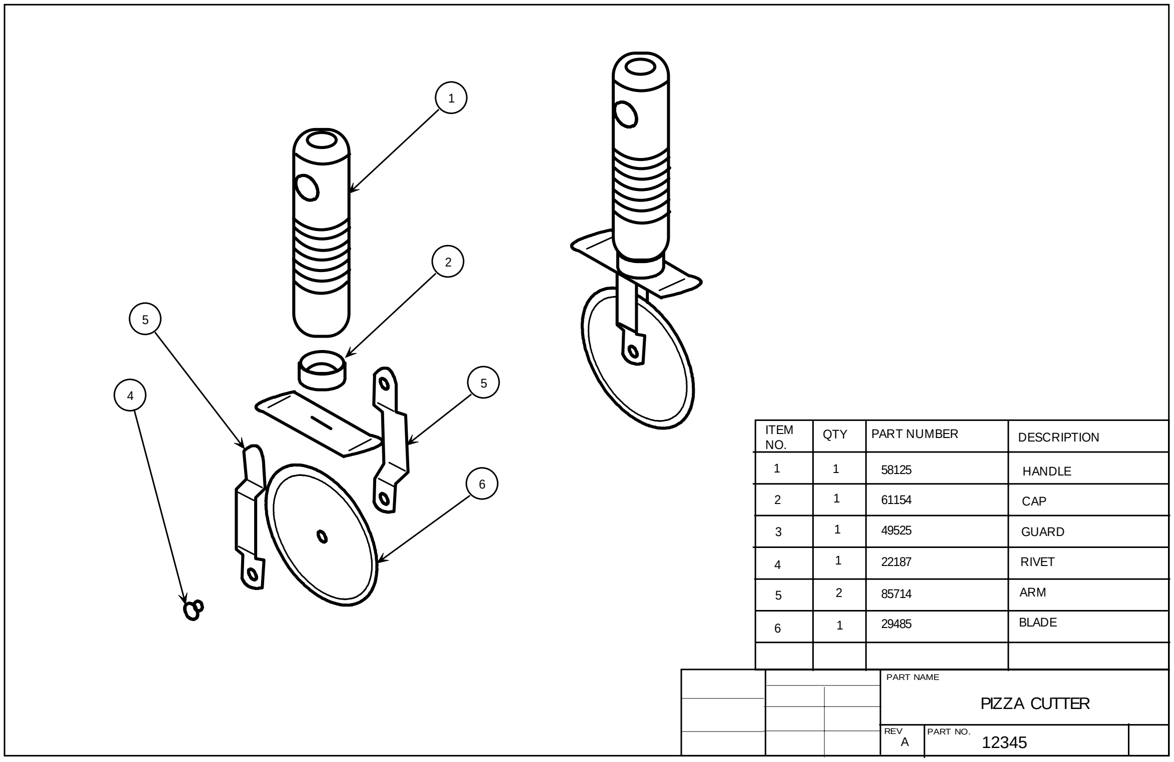
2. Interference– fit having limits of size so that there is always ____________ between mating parts that are in spec.
   a. Pins "in spec" are always BIGGER than holes "in spec".
   b. These parts must be pressed or forced together.
   c. Example – a hole of ∅ 1.0000 ± .0005 and a pin 1.0010 ± .0005.

3. Transition – fit having limits of size so that a _________ or ____________ fit results between mating parts in spec.
   a. Pins may be BIGGER or SMALLER than holes.
   b. Example – a hole of ∅ 2.000 ± .001 and a pin 2.000 ± .001.



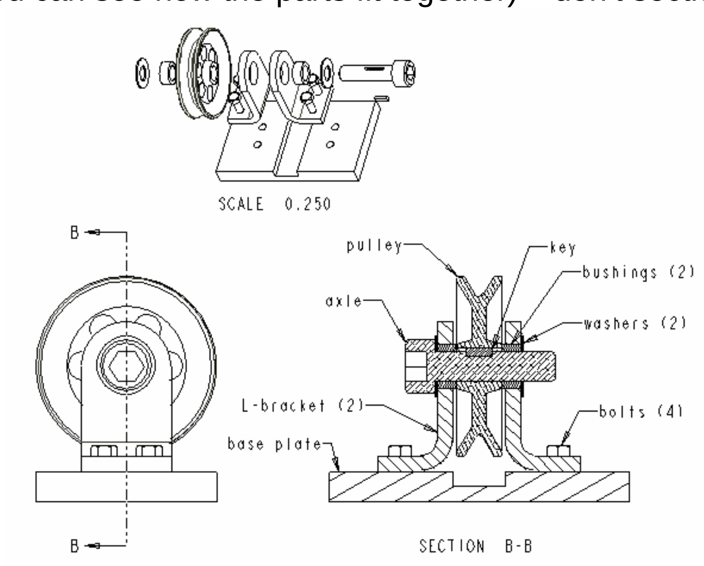
IX. ASSEMBLIES

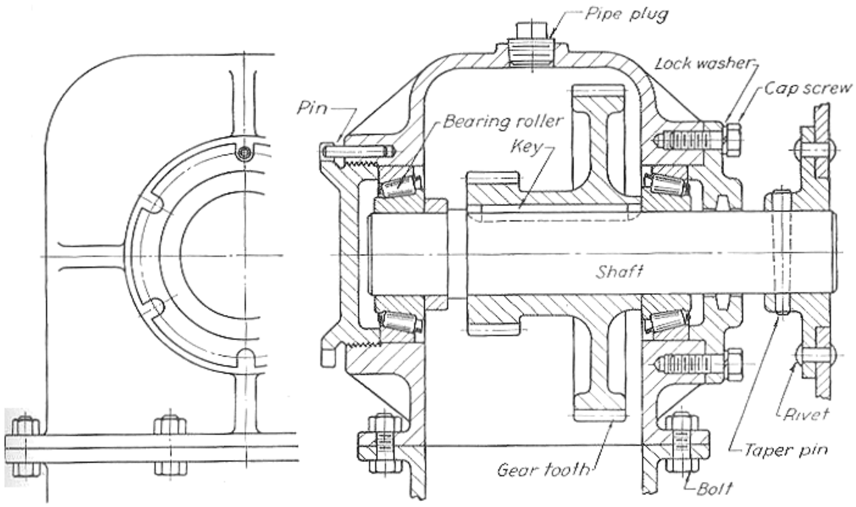
A. What are they?
   1. Assemblies are _______________ that ____________ to form a machine or mechanism
B. Assembly drawings
   1. Assembly drawing – shows the assembly its _________ state.
   2. Bill of materials (BOM, or item list)
      a. List of materials that make up the assembly
      b. Item number, quantity, part number, description
   3. Balloons – circled number that denotes the item number



ITEM NO.	QTY	PART NUMBER	DESCRIPTION
1	1	58125	HANDLE
2	1	61154	CAP
3	1	49525	GUARD
4	1	22187	RIVET
5	2	85714	ARM
6	1	29485	BLADE

C. State of the assembly
1. Assembled
2. Exploded
3. Sectioned (so you can see how the parts fit together) – don’t section fasteners





Section study.

X. AutoCAD

A. Adding tolerances
   1. Use properties palette
   2. Tolerances
   3. Dropping leading zero (under tolerances, suppress leading zero)

B. Changing number places on dimension – use properties palette
   1. Primary units/ precision

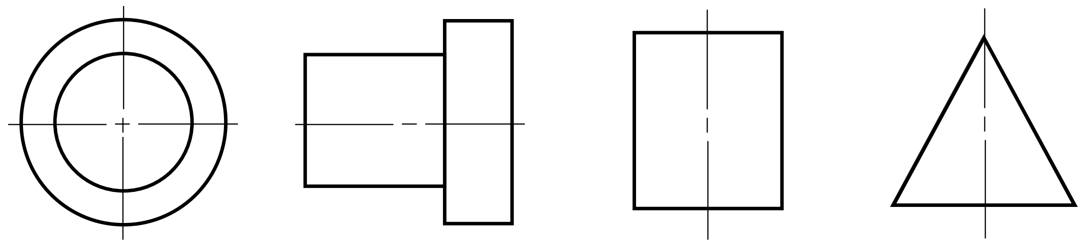
C. Assemblies
   1. Creating tables for BOM
   2. Creating balloons

13 ANNOTATIONS & FEATURES

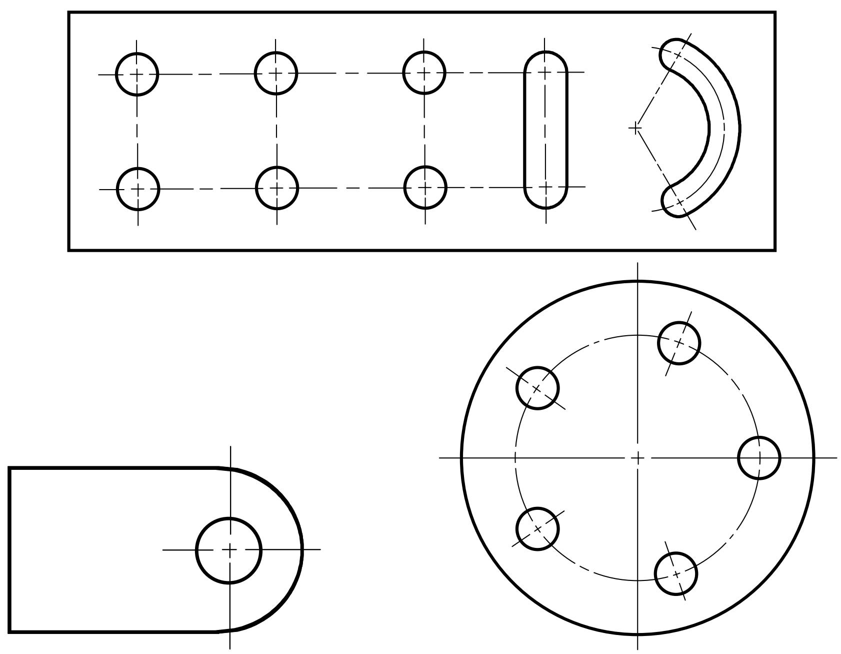
I. Preliminaries

II. Centerlines indicate…

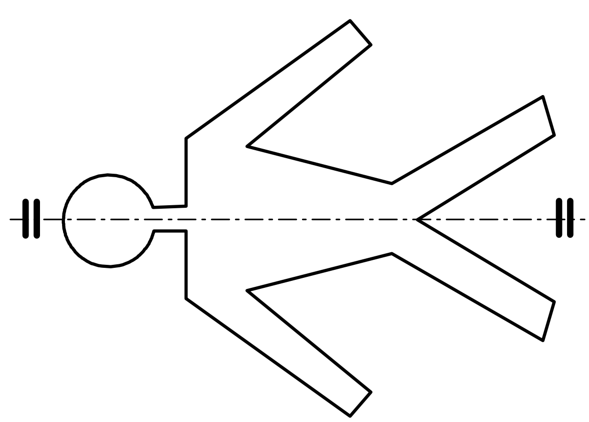
A. Centers of rotation (as in circles, cylinder, cones, etc.)



B. Alignment of holes (rectangular, circular), radii, curves, slots…

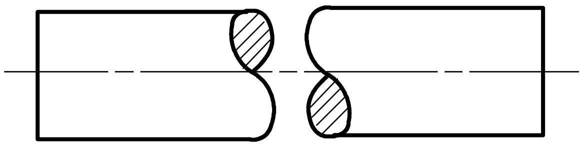


C. Symmetry (bilateral)



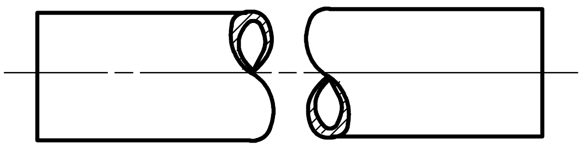
III. Conventional breaks

A. Long bars with ________ cross section.
B. Rectangular, rounds, pipes, tubes, wood, etc.



ROUND CROSS-SECTION

WOOD
(RECTANGULAR SECTION)



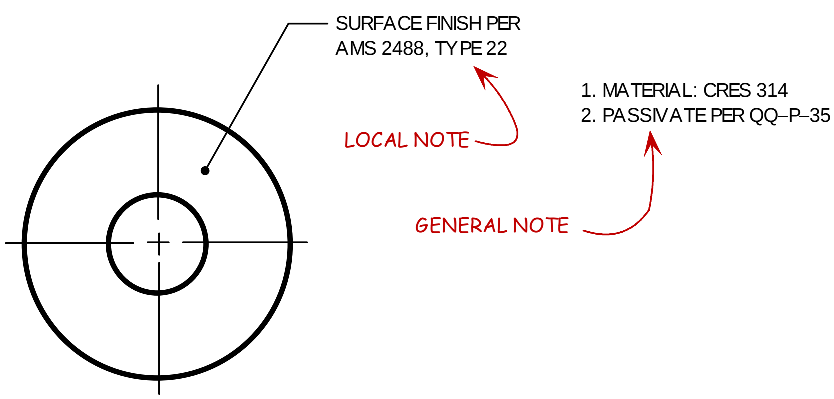
ROUND TUBING

IV. Symbols

Symbol	ANSI/ASME	OLD STYLE
Diameter	∅	1.00 D or 1.00 DIA
Radius	R.25	.25 R
Multiple holes	2X ∅1.00	1.00 DRILL, 2 HOLES
Multiple instances	2X R.25	.25R, 2 PLCS
Thread	10-24 UNC	10-24 UNC THD
Reference Dimensions	(1.00)	1.00 REF
Chamfers	.01 x 45°	.01 x 45° CHAMFER

V. Notes

A. General notes
   1. Usually apply to the ________ part (e.g., a material callout)
   2. Example: MATERIAL: STAINLESS STEEL 316 (or CRES 316)
B. Local notes
   1. Usually apply to a ____________________ of the part.
   2. Requires a leader (an arrow to point to the region of interest)

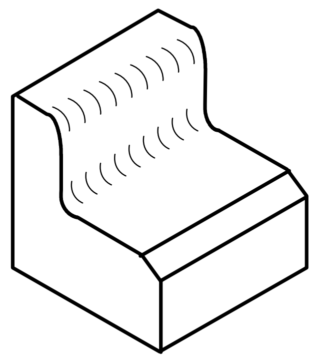


VI. Common features

A. Chamfer
   1. ________ into an edge (often 45 degrees)
   2. Specification for ____ removal
   3. "______" for pins that are to be pressed into a tight hole.

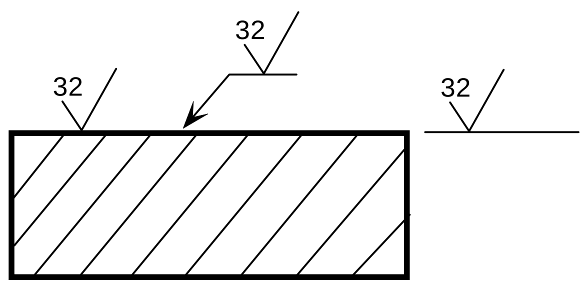
B. Fillets
   1. A rounded filling of an ________ edge between 2 surfaces
   2. Used to __________.

C. Rounds (or radius)
   1. A rounded _______ edge
   2. For _________.

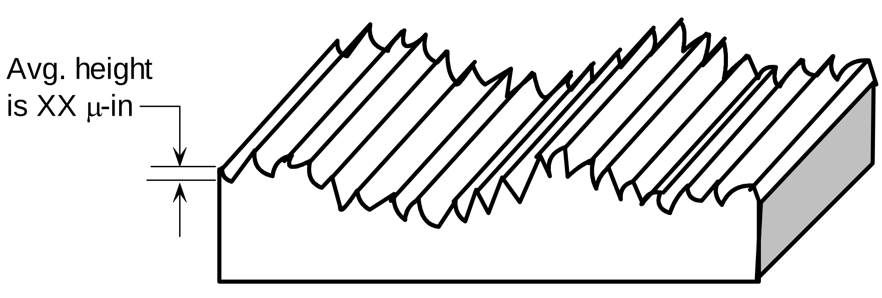


VII. Surface finish

A. Examples of surface finish callout



B. Meaning – the average _________ height in μ (Greek letter "mu" = one millionth) inches.



C. Default value is often called out on ____________ (e.g., 32 rms)

VIII. AutoCAD – altering dimension callout, general notes

14 FASTENERS, HOLES, & THREADS

I. Preliminaries

A. (CT brings – fasteners, SW file of threaded part, hole types, thread computer)

II. Fasteners

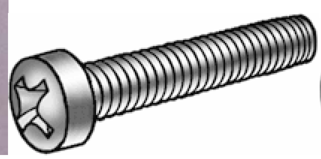
A. Mechanical devices for ________ parts together (screws, bolts, rivets, clips)
B. Threaded fasteners – such as bolts and screws – are most common.
C. Screws (many different types!)
   1. ____________ cap screws – have hexagonal recess drive
   2. Hex head screws – have protruding hexagonal head
   3. __ head – flat on top, rounded edges
   4. Button head – round on top (but not full round)
   5. Flat head

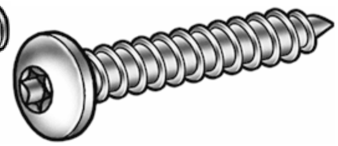

socket head c.s.


hex head cap screw

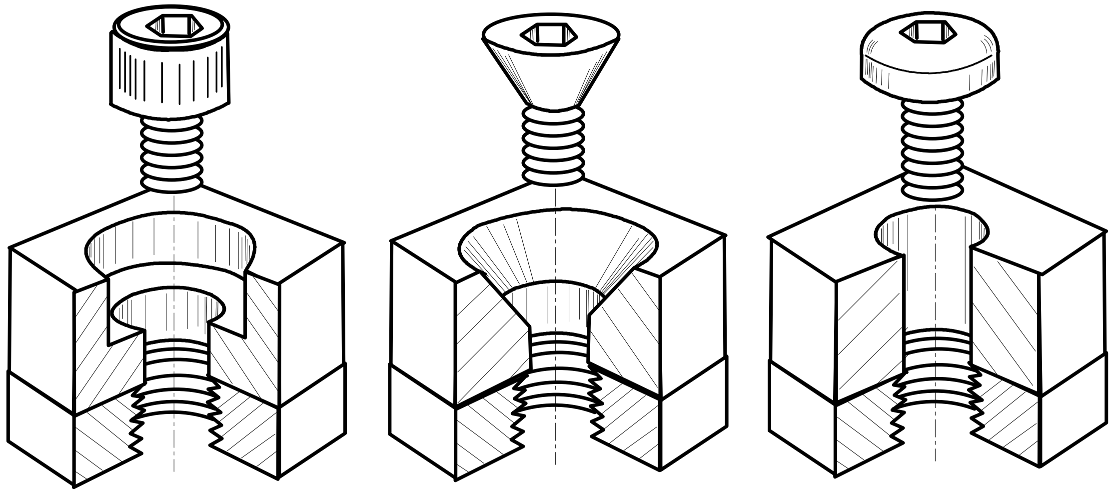

button head cap screw


flat head cap screw


fillister head c.s.


sheet metal screw

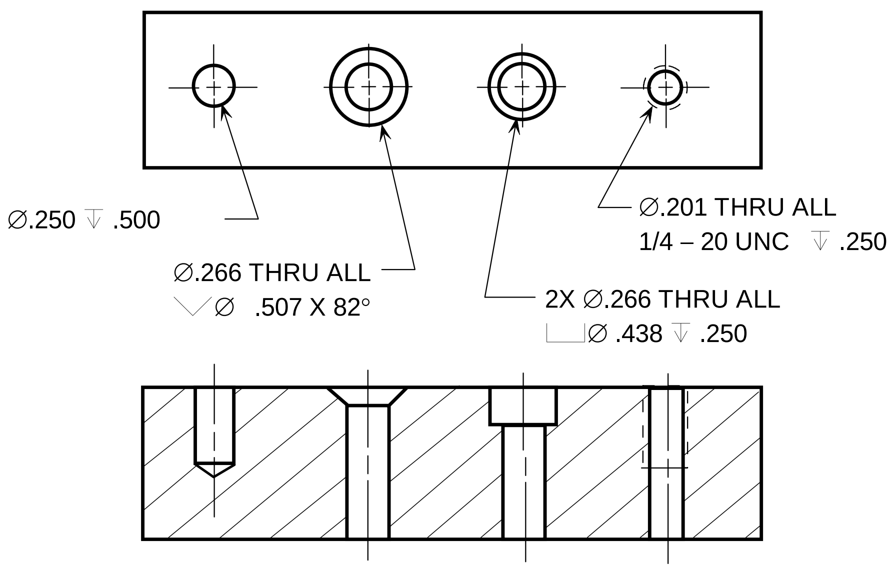
III. Hole types



COUNTERBORE HOLE & SOCKET HEAD CAP SCREW

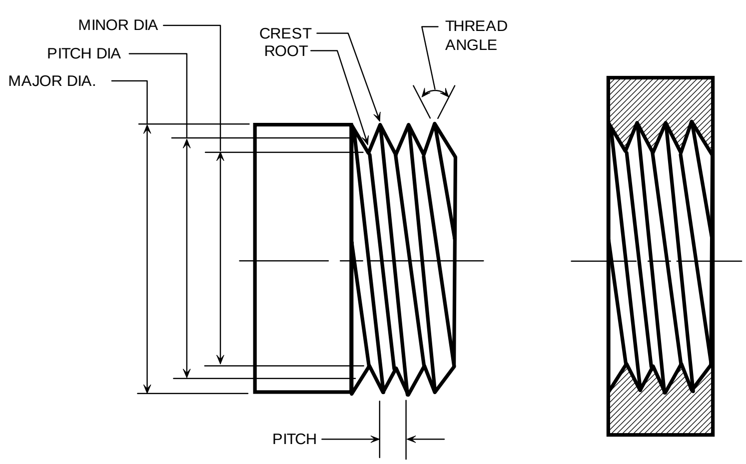
COUNTERSINK HOLE & FLAT HEAD CAP SCREW

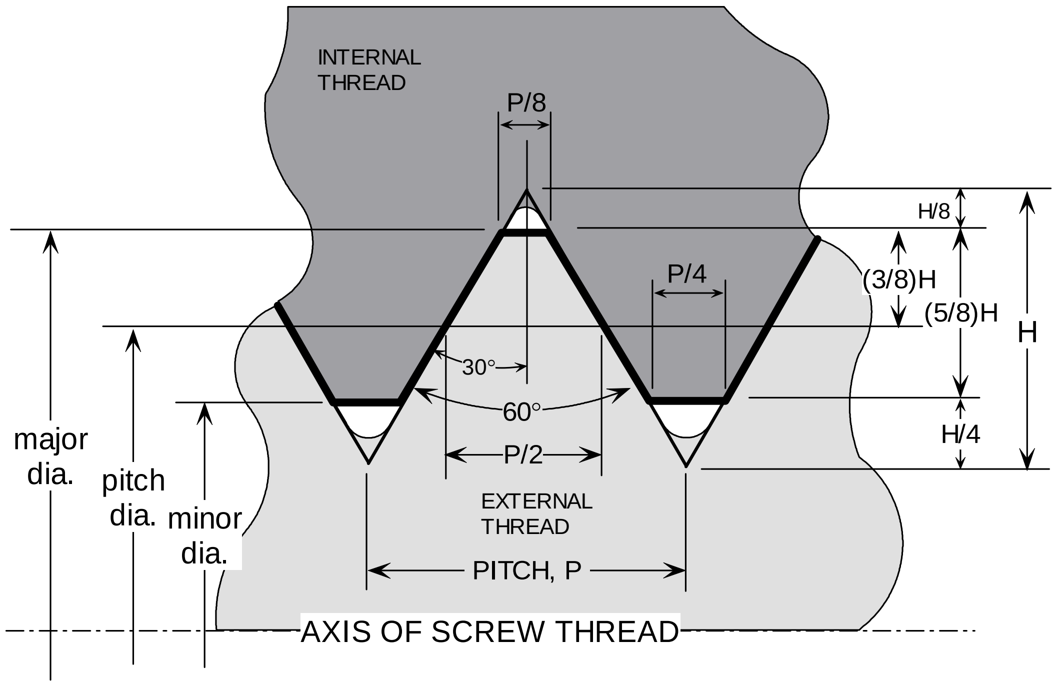
PLAIN HOLE & PAN HEAD CAP SCREW



IV. Threads

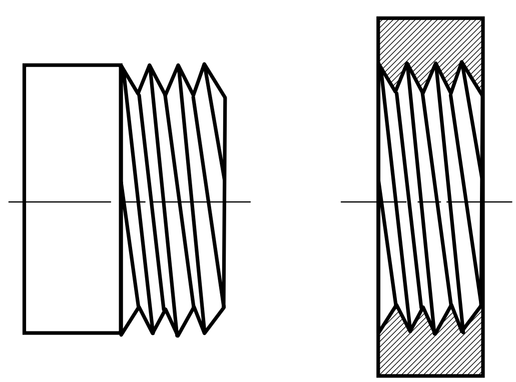
A. Thread geometry– a projecting _______ ridge formed on a shaft, by which parts can be _______ together



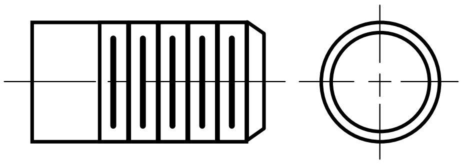


B. Thread terminology
1. External (male) thread – an "_____"
2. Internal (female) thread – an "_____"
3. Crest – _____ edge of the thread
4. Root – _____ edge of the thread
5. Major diameter – ______ diameter of the male thread
6. Minor diameter – _______ diameter of the male thread
7. Pitch – distance between ________ crests
8. Lead – distance part moves _______ over 1 rotation
9. Thread angle – usually 60 degrees for "_______" threads
10. Right-handed vs. left handed – use the right hand rule
11. Threads per inch – number of XXX per inch.
12. NPT (National pipe thread) – tapered pitch diameter
13. UNF (Unified National Fine) – the thread series
14. UNC (Unified National Coarse) – also a thread series

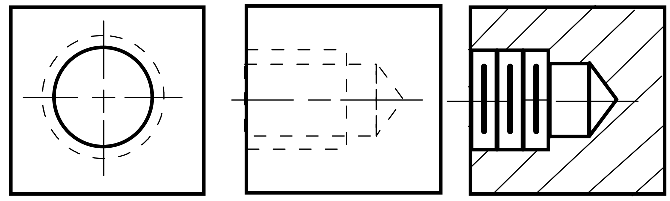
C. Thread symbols (how to display threads on drawings)
1. Detailed



2. Schematic

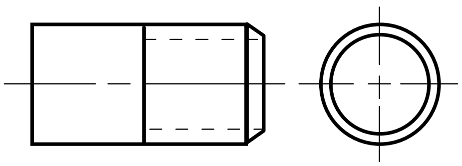


SCHEMATIC EXTERNAL THREAD

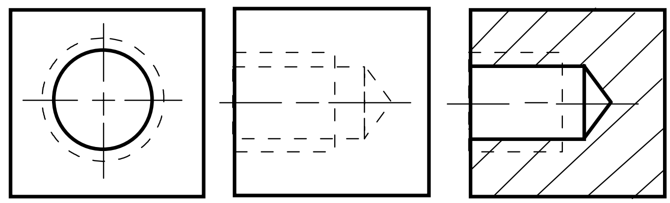


SCHEMATIC INTERNAL THREAD

3. Simplified

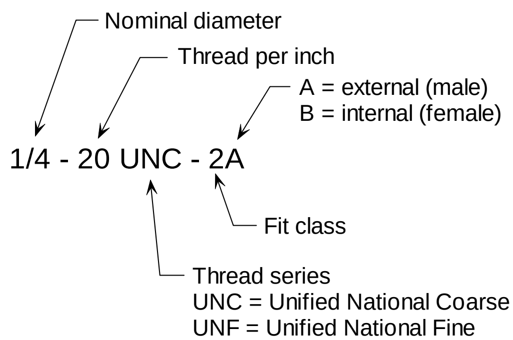


SIMPLIFIED EXTERNAL THREAD



SIMPLIFIED INTERNAL THREAD

D. Thread callouts



1. Other callouts: 5/16-18 UNC (no "2A")
2. Another callout: #10-24 UNC (#10 is a "nominal" value)

E. Types of threads
1. _____ handed vs. ______ handed – add "_____" at end of callout if left-handed.
2. Single vs. double – number of distinct crest _____.
3. Thread series
   a. UNF (_____) vs. UNC (______) – different threads per inch, but __________ diameter
4. Fit class
   a. 1 = _______ fit.
   b. 2 = most ______.
   c. 3 = most _____.

F. Fabricating threads
1. Tap – for female thread
2. Die – for male thread

V. Metric thread callout

A. Example – M10 x 1.5
1. "10" = ________________. (mm)
2. "1.5" = _____. (mm)

B. For coarse threads, pitch may be omitted (so "M10 x 30"), then 30 means ______.
1. You know it's length if the value is > 6 (usually)

VI. AutoCAD - X

A. Detailed

1. Establish _____ diameter.
2. Establish _____ positions for side 1– for single thread, distance between crests should be 1/________________.
3. Establish crest positions for side 2 – which should be offset from those on side 1 by ____ distance.
4. For machine threads, the thread angle is 60 degrees. This then establishes the _____ diameter.
5. Note – this is just an ________!

B. Schematics – spacing is any convenient value (crest, root lines).

C. Simplified –

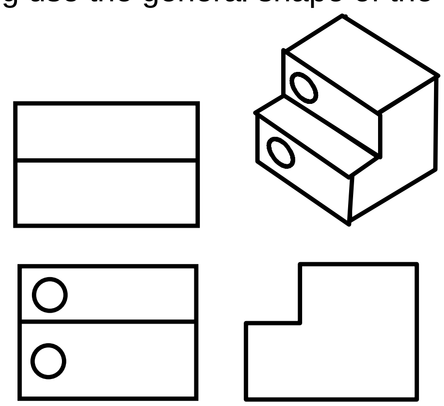
15 PICTORIALS & OTHER CAD

I. Preliminaries

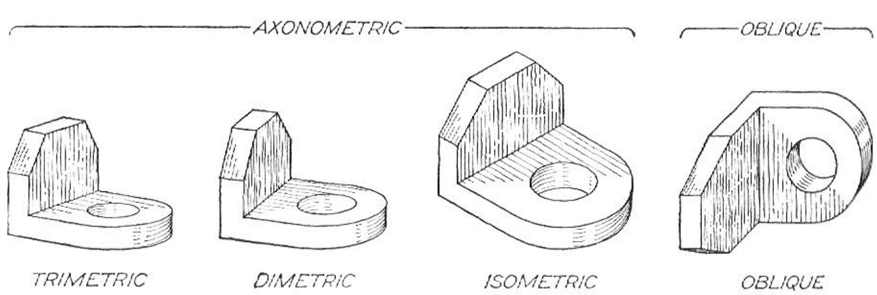
   A. (CT brings – SW hand robot)
   B. Last time
      1. Threads, fasteners, hole types

II. Intro to Pictorials

   A. Easier to see general part shape
   B. 3 types
      1. Axonometric
      2. Oblique
      3. Perspective
   C. Comparing pictorials and orthographic views
      1. Pictorials
         a. Good at conveying the ____________ and ________ of a part
         b. Not good at conveying ________ size info (e.g., are holes _______?).
         c. Not good at telling exact shapes w/o __________ – (e.g. are holes round?)
      2. Orthographic views
         a. Often not good at telling use the general shape of the part.

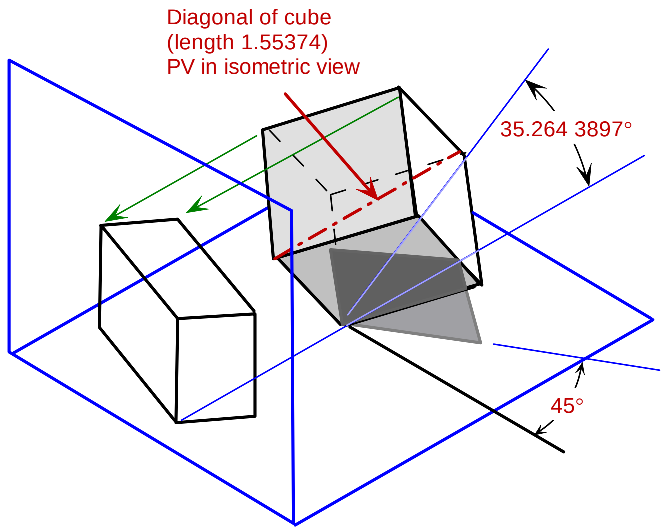


III. Axonometric

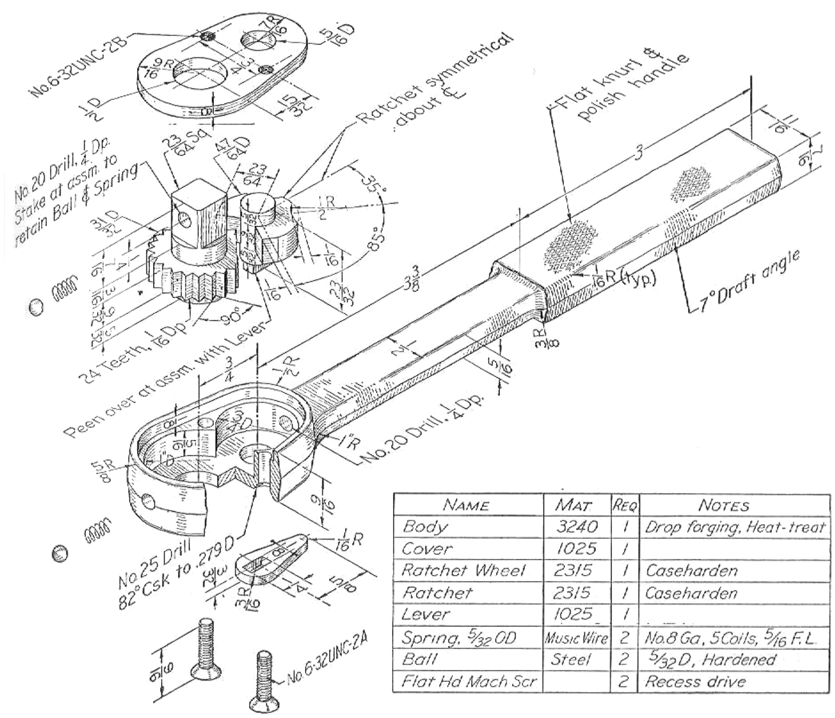


Pictorial methods.

   A. Geometric concept – we project ________ lines of sight onto a viewing plane (just like with normal orthographic views), but now the part is ___________ in the "glass box" so that 3 sides show.
      1. Isometric
         a. Rotate the cube by 45° in the horizontal plane.
         b. Tip the cube up off the horizontal plane by 35.264°.



B. Features become _________ – circles look like ellipses, etc.



Name	Mat	Req	Notes
Body	3240	1	Drop forging, Heat-treat
Cover	1025	1	
Ratchet Wheel	2315	1	Caseharden
Ratchet	2315	1	Caseharden
Lever	1025	1	
Spring, 5/32 OD	Music Wire	2	No.8 Ga, 5 Coils, 5/16 F.L.
Ball	Steel	2	5/32 D, Hardened
Flat Hd Mach Scr		2	Recess drive

Fig. 28.59. Ratchet wrench.

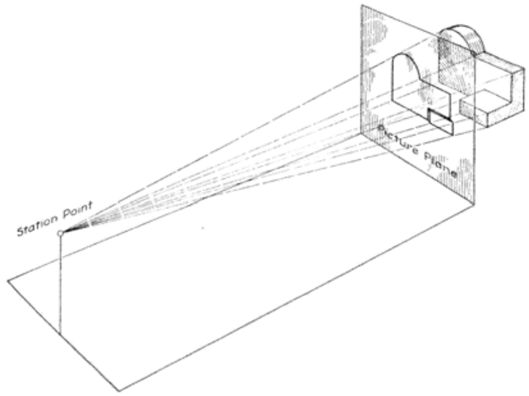
A set of drawings from a pictorial assembly

IV. Oblique

A. Don't think of the object as ______ or rotated.
B. Major (front) face stays parallel to projection plane (like orthographic view)
C. A receding (depth) axis is drawn at a convenient angle (30, 45 etc.)
D. Good for objects of same cross-section (like structural tubing)
E. Make the front surface one with the most complex stuff on it (easier to draw!)

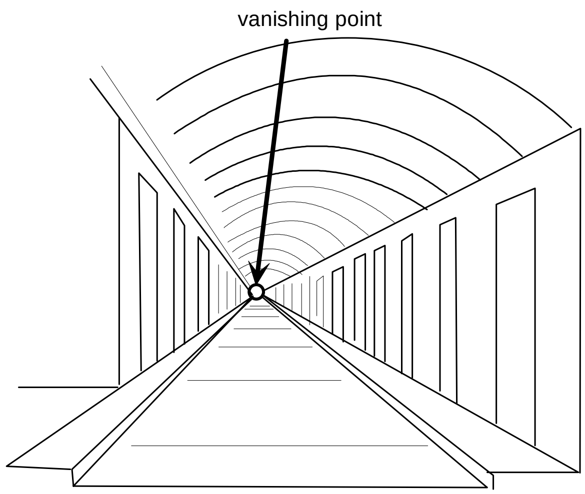
V. Perspectives

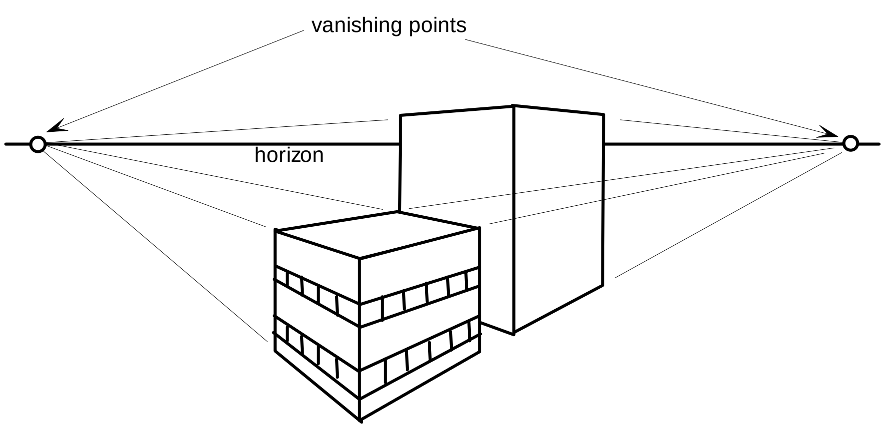
A. Created by ____________ lines of sight projected onto viewing plane.

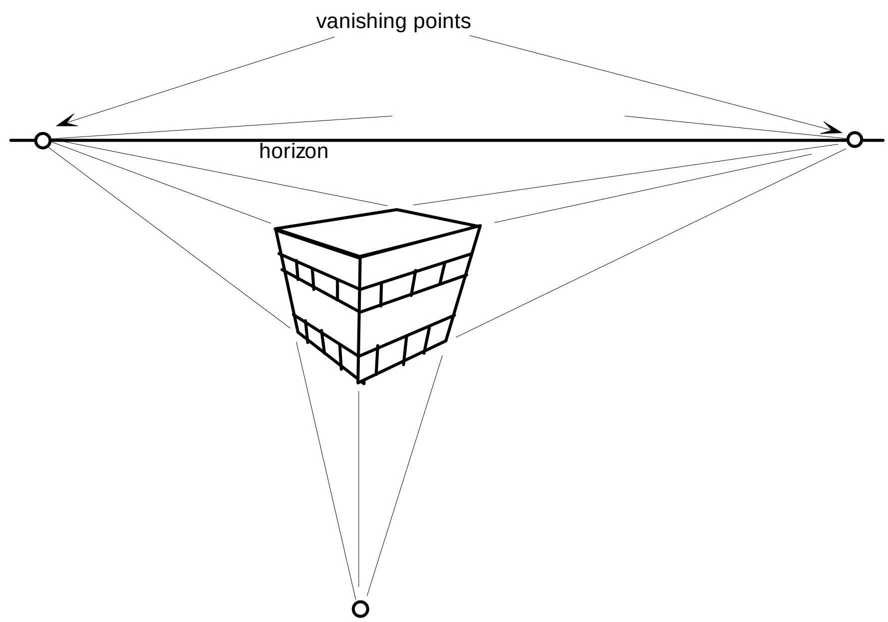


B. _______________ - objects appear _______ the _______ away they are from the _____________ because their observed size comes from the __________ of "full range of view" the object takes up. So objects have ____ size at ________ distance (_________ point!).

C. 1-point perspective – 1 vanishing point.
D. 2-point perspective – 2 vanishing points.
E. 3-point perspective – 3 vanishing points.







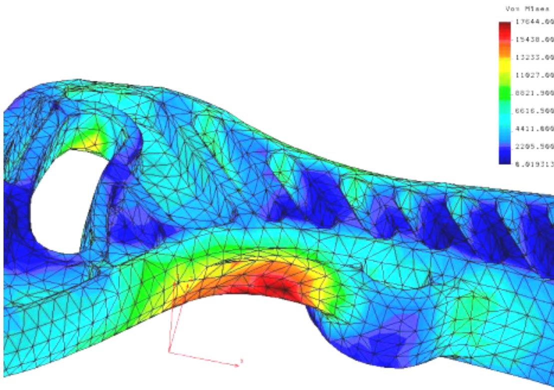
16 FINAL EXAM & FINAL THOUGHTS

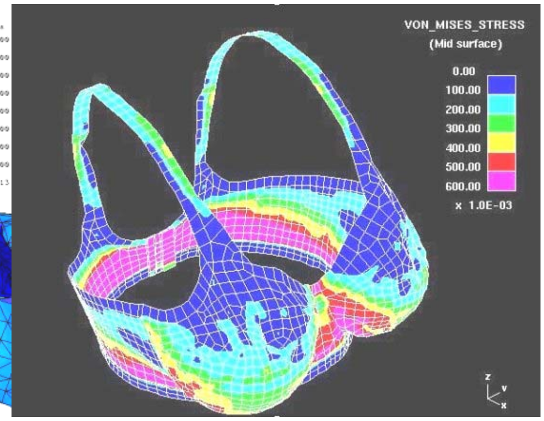
I. SAC Degree & Certificate Program

II. 3D Parametric Solid modeling

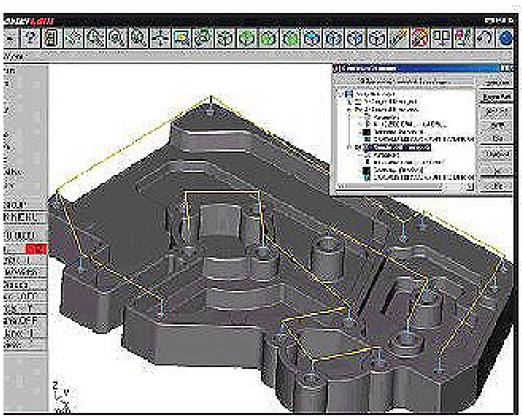
A. The Program
1. 3D parametric solid modeling (Solidworks, CATIA, ProEngineer)
   a. 3D – parts are conceived in 3 dimensions
   b. Parametric – the dimensions drive the geometry
   c. Solid modeling – all points are distinguished as either on the interior or exterior of the part.
2. Modes
   a. Part – you make a virtual version of the part you are designing
   b. Assembly – assembly of several different parts (requires the ability to think about geometric constraints)
   c. Drawing – basically the software makes the part views, based on the part model (though there's a lot of detail you must still do on your own)
3. Other features
   a. Bi-directional associativity – change the drawing → part is changed too
   b. COSMOS – finite element analysis
   c. Photoworks – create photo-realistic images and video (marketing)

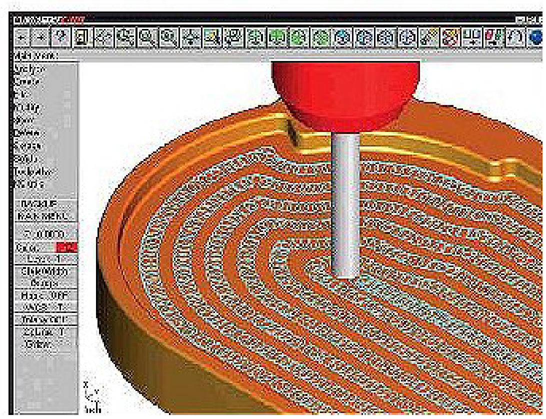
B. Advantages of 3D modeled parts – the models are readily used for other things
1. CAE (computer-aided engineering) or FEA (finite element analysis)
   a. Computes internal ________ & ________ that result when you apply virtual (computerized) ____________. Predicts how parts will behave (or fail) during actual _______.





2. Rapid prototyping
    a. CAM (computer-aided manufacturing) – uses the 3D model to define a ____ ____ to machine the part on a CNC (computer numerical control) machine





    b. Stereolithography (SLA) – building plastic parts ________ at a time using a laser that traces over a vat of liquid photopolymer.

    c. 3D printing

3. Photorealistic renderings (for marketing)

III. Bottom Line

A. Mechanical engineers – okay to know AutoCAD, but also should know some parametric solid modeling software (Solidworks, ProEngineer, CATIA, Unigraphics/NX, etc.).
B. Electrical engineers – use Orcad by Cadence
C. Civil engineers – use AutoCAD (& Civil 3D)
D. Architects – use AutoCAD (but now there's Revit)

IV. Final exam topics

A. Tolerancing & Assemblies
   1. Tolerancing basics – YES
   2. Tolerances - definition, why they exist, basic rules, terminology – YES
   3. Manufacturability – no
   4. Tolerance forms, specifying tolerance – YES
   5. Tolerances & manufacturing – don't memorize tables
   6. Determining tolerances – no
   7. Fits – terminology, 3 general fits – YES
   8. Assemblies – what they are, drawings, BOM, balloons – YES
   9. How assemblies are drawn – assembled, exploded, sectioned – YES
B. Annotations & Features
   1. Centerlines indicate what? YES
   2. Conventional breaks, broken views – YES
   3. Notes – general, local – YES
   4. Common features – fillets, rounds, chamfers – YES
   5. Surface finish callouts – YES
C. Fasteners, Holes, Threads
   1. Fasteners – identify SHCS, Hex head CS, button head CS, flat head CS – YES
   2. Match hole type to fastener – YES
   3. Hole callouts – YES
   4. Threads – terminology, 3 ways to draw, callouts – YES
D. Pictorials
   1. Name 3 types – YES
   2. Axonometric – name 3 types – YES
   3. Oblique vs. isometric – be able to distinguish – YES
   4. Perspectives – what are 3 types, be able to distinguish – YES
E. Note – for make-up exams, ALL material in notes & discussed in class are fair game.

V. Continuing from here

A. Architectural / civil drafting & design. Take...
   1. Engr 183 (AutoCAD I)
   2. 184 (AutoCAD II)
   3. 142 (AEC Drafting Practices)
   4. 154 (Architectural drafting with Revit)
   5. Later – 185, 186, 187, 201, 191, 193 (Microstation)

B. Mechanical/ industrial/ aerospace/ biomedical. Take...
   1. Engr 124 – Advanced Drawing
   2. Engr 130A – CATIA I Solid Modeling
   3. Engr 140A – ProEngineer I Solid Modeling
   4. Optional – 132 (robotics),
   5. Later – 130B (CATIA II), 140B (ProE II), 183 (AutoCAD I)