ANSWERS of MAK422E Engineering Design and CAD Final Exam, Jan. 20, 2011

1. **(20)** Consider a 2D problem, the triangle formed by end points $\mathbf{P_1=(2,1)}$, $\mathbf{P_2=(6,1)}$, $\mathbf{P_3=(2,3)}$. It is desired to create a rotation transformation that will cause an object to be rotated $\boldsymbol{\alpha=40^o}$ about a point defined by $\mathbf{P_1}$. Determine the necessary 2D transformation matrix, **T**, that will accomplish this, and calculate the final coordinates of the object vertices.

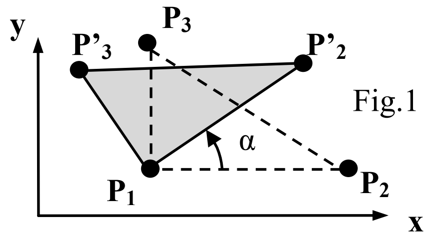


Fig.1

The solution by using basic 2D rotation matrice:

$$P_1 := \begin{pmatrix} 2 \\ 1 \end{pmatrix} \quad P_2 := \begin{pmatrix} 6 \\ 1 \end{pmatrix} \quad P_3 := \begin{pmatrix} 2 \\ 3 \end{pmatrix}$$

$$\alpha := 40 \cdot deg \quad c\theta := \cos(\alpha) \quad s\theta := \sin(\alpha) \quad T := \begin{pmatrix} c\theta & -s\theta \\ s\theta & c\theta \end{pmatrix}$$

$$P'_2 := T \cdot (P_2 - P_1) + P_1 \qquad P'_3 := T \cdot (P_3 - P_1) + P_1$$

The solution by using 2D homogenous transformation matrices:

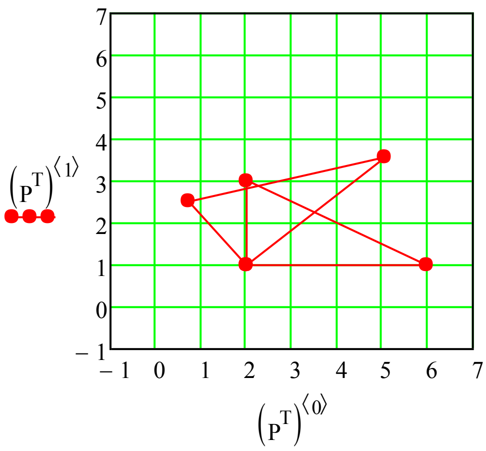
$$P_1 := \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} \quad P_2 := \begin{pmatrix} 6 \\ 1 \\ 1 \end{pmatrix} \quad P_3 := \begin{pmatrix} 2 \\ 3 \\ 1 \end{pmatrix} \quad T := \begin{pmatrix} 1 & 0 & 2 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix} \quad T1 := \begin{pmatrix} 1 & 0 & -2 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{pmatrix}$$

$$Rz(\alpha) := \begin{pmatrix} \cos(\alpha) & -\sin(\alpha) & 0 \\ \sin(\alpha) & \cos(\alpha) & 0 \\ 0 & 0 & 1 \end{pmatrix} \qquad T \cdot Rz(\alpha) \cdot T1 = \begin{pmatrix} 0.766 & -0.643 & 1.111 \\ 0.643 & 0.766 & -1.052 \\ 0 & 0 & 1 \end{pmatrix}$$

$$P'_2 := T \cdot Rz(\alpha) \cdot T1 \cdot P_2 \qquad P'_2 = \begin{pmatrix} 5.064 \\ 3.571 \\ 1 \end{pmatrix} \qquad P'_3 := T \cdot Rz(\alpha) \cdot T1 \cdot P_3 \qquad P'_3 = \begin{pmatrix} 0.714 \\ 2.532 \\ 1 \end{pmatrix}$$

All points may be collected in one matrix for drawing purpose

$$P := \text{augment}(P_1, P_2, P_3, P_1, P'_2, P'_3, P_1) \qquad P = \begin{pmatrix} 2 & 6 & 2 & 2 & 5.064 & 0.714 & 2 \\ 1 & 1 & 3 & 1 & 3.571 & 2.532 & 1 \end{pmatrix}$$



2. **(20)** How long is the projection of the vector $\mathbf{P_1=(1,3)}$ onto the vector $\mathbf{P_2=(7,6)}$? Calculate the coordinates of the projection point $\mathbf{P_3}$. Use vector algebra. $\mathbf{A \cdot B = |A|.|B|.\cos(\theta)}$ $\quad \mathbf{|A x n| = |A|.1.\sin(\theta)}$

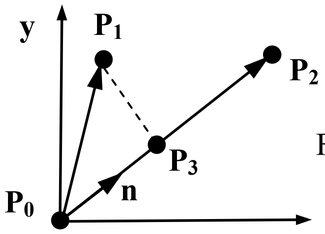
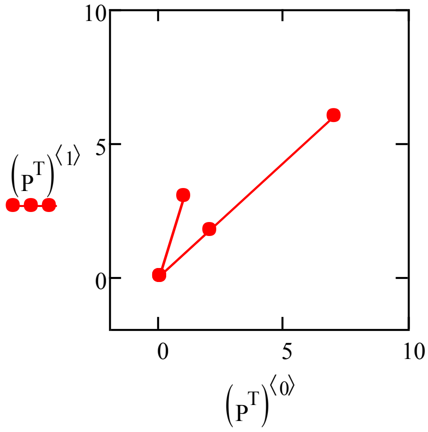


Fig.2



$$P_0 := \begin{pmatrix} 0 \\ 0 \end{pmatrix} \quad P_1 := \begin{pmatrix} 1 \\ 3 \end{pmatrix} \quad P_2 := \begin{pmatrix} 7 \\ 6 \end{pmatrix} \quad |P_2| = 9.22 \quad n := \frac{P_2}{|P_2|} \quad n = \begin{pmatrix} 0.759 \\ 0.651 \end{pmatrix} \quad P_1 \cdot n = 2.712$$

$$u := \frac{P_1 \cdot n}{|P_2|} \quad u = 0.294 \quad P_3 := 0 + u \cdot P_2 \quad P_3 = \begin{pmatrix} 2.059 \\ 1.765 \end{pmatrix} \quad P_3 := P_0 + n \cdot (P_1 \cdot n) \quad P_3 = \begin{pmatrix} 2.059 \\ 1.765 \end{pmatrix}$$

All points may be collected in one matrix for drawing purpose

$$P := \text{augment}(P_0, P_1, P_0, P_2, P_0, P_3) \qquad P = \begin{pmatrix} 0 & 1 & 0 & 7 & 0 & 2.059 \\ 0 & 3 & 0 & 6 & 0 & 1.765 \end{pmatrix}$$

3. **(10)** Write the solid modeling methods in CAD.

There are many ways to model a part,
the major categories are,

Surfaces (such as polygons)

Elemental (using lines and points like drafting)

Boundary Representation (B-rep)

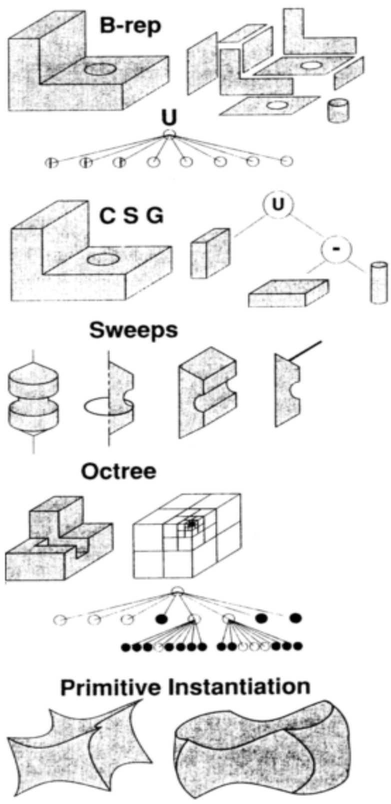
Constructive Solid Geometry (CSG)

Sweep

Hybrid (feature based modellers)

Tessellated Models, Octree Model

Primitive Instantiation, Analitical Solid Modeling (ASM)



4. **(10)** What are the main principles of Design for Assembly?

Design for Assembly
Minimize number of parts, avoid several directions of assembly, and maximize assemblability through guidance features.
Examine the product to recognize conditions for the elimination of parts:
Does the part move after the assembly?
Why must the part be of a different material than the neighbouring part?
Would the part prevent the assembly of other parts, if it were to be combined with a neighbouring part?

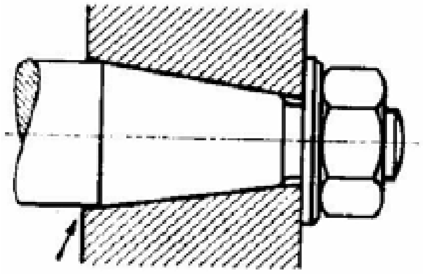
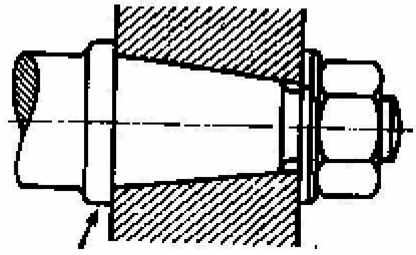
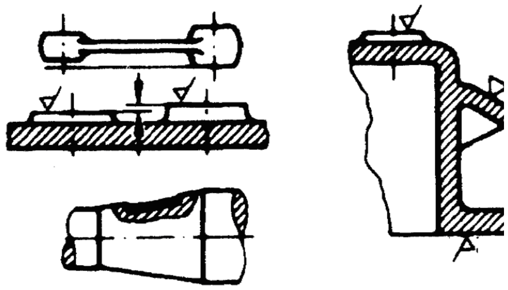
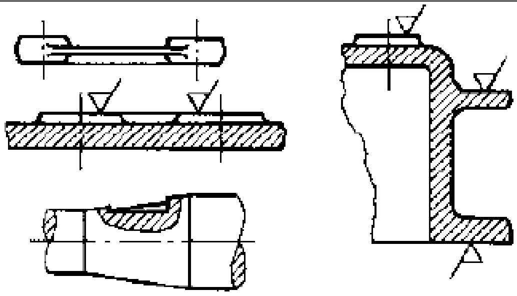
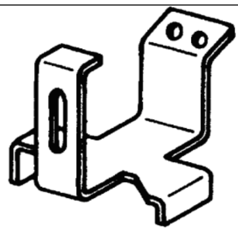
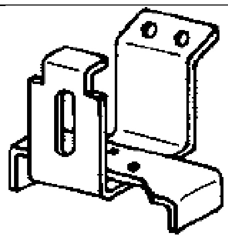
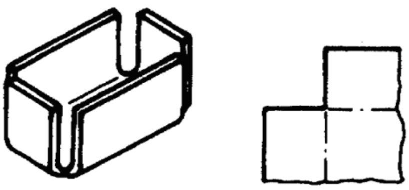
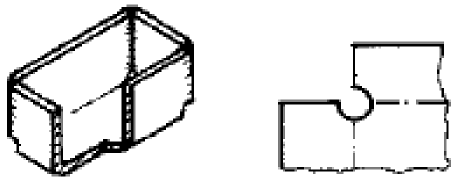
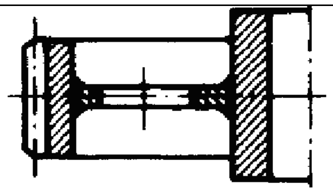
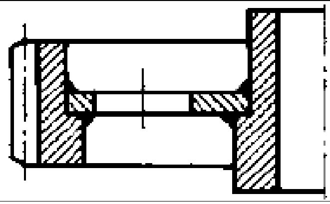
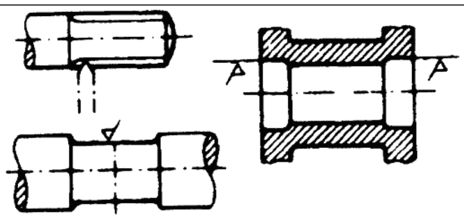
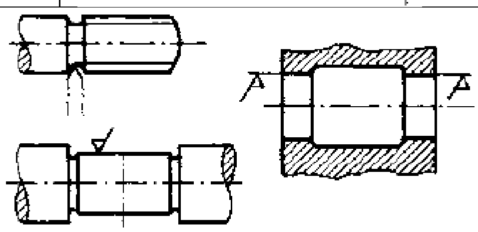
The Assembly from Heaven*
• Can be assembled one-handed by a blind person wearing a boxing glove
• Is stable and self-aligning
• Tolerances are loose and forgiving
• Few fasteners
• Few tools and fixtures
• Parts presented in the right orientation
• Parts asymmetric for easy feeding
• Parts easy to grasp and insert

The Assembly from Hell
• The opposite in each case from the previous slide

Conventional DFA
• The issues are: (Boothroyd except where noted)
– assembling each part -estimating and reducing time
• feeding/presenting
• handling/carrying/getting into position (Sony exploded views)
• inserting without damage, collisions, fumbling
– reducing part count (originally driven by local economic analysis, now driven by part cost itself)
• two adjacent parts of same material?
• do they move wrt each other after assembly
• is disassembly needed later (use, repair, inspection, upgrade...)
• is the part a main function carrier?(Fujitsu, Lucas, (Pahl & Beitz))
• if not, consider combining them (but see Architecture class)
• are there too many fasteners?
- identifying cost drivers (Denso)

DFA at Sony
• Applied to products like Handicams
• "Our designers take assembly into account early."
• Method:
– concept designs are sketched in exploded views
– each concept is subjected to DFA analysis and scored
– concept selection criteria include DFA score
• A Sony engineer made a complete exploded view drawing of a Polaroid camera in 20 minutes!

5. **(20)** How can you improve following design in terms of DfX (material, manufacturing process and assembly)? Draw sketches and explain.

<table>
<tr><td>
a).</td><td></td><td></td></tr>
<tr><td colspan="3">Avoiding double fits: a Tapered shaft–hub connection with interference (shrink) fit. The simultaneous axial location against the shaft collar and the taper seat creates a double fit: the radial pressure due to the interference fit cannot be determined. The right solution would be to use either a taper without a shaft collar or to use a cylindrical seat with a shaft collar.</td></tr>
<tr><td>b).
</td><td>Arrange surfaces on one level and parallel to the clamping.</td><td></td></tr>
<tr><td>
c).</td><td>Avoid complex bent parts (material waste), rather split and join.</td><td></td></tr>
<tr><td>
d).</td><td>Provide clearances at the corners when all sides are to be bent up.</td><td></td></tr>
<tr><td>
e).</td><td>Ensure positive location of the components prior to welding.</td><td></td></tr>
<tr><td>
f).</td><td>Provide adequate tool run out.</td><td></td></tr>
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6. **(10)** What is the reason of using the group technology?

Deep background in Group Technology
– classification schemes

Group-Technology Based Design

Premise: Fast access to pertinent (similar) historical data available within the enterprise and its modification for the design and fabrication of new parts within the same family.
Classification of a population of similar products can help standardizing parts or even modularize them.
If the GT system includes modules for process planning, fixture selection, and other manufacturing issues, at the time of information retrieval for the "most similar" past product, one can review this information to make better design decisions on manufacturability, etc.

History of Group Technology

1930-1950: Sokolovski and Mitrofanov develop GT in the former USSR: Advocate that parts of similar geometry and materials should be manufactured in the same way by standardized technological processes within physical workcells.
1950s: Development of the Brisch & Birn coding and classification method in the U.K.
1960s: Development of OPITZ in Germany - today's most commonly used GT system in Europe.
1970s: Development of MICLASS in the Netherlands - today's most commonly used GT system in U.S.A.

Classification
Classification: Logical and systematic way of grouping things based on their similarities, but, then, sub-grouping them according to their differences:
All-embracing: Classify all current parts, but, also allow for future product features.
Mutually exclusive: A part should have only one class to be included within.
Based on permanent features: Utilize only the final geometrical features of the part.
From a user's point of view.

Implementation
Once a company has developed and installed a GT system, either a large set of past products are coded immediately or only new future parts are coded as they arrive:
Code a new part based on available sketchy information,
Request the GT system to identify and retrieve the most similar part model from the database, and
Decide whether it would be more economical to modify this past model rather than starting from scratch.

7. **(10)** Write the Rapid Prototyping methods?

1) Rapid Prototyping Techniques
2) Stereolithography
3) Laminated Object Manufacturing
4) Selective Laser Sintering
5) Fused Deposition Modeling
6) Solid Ground Curing
7) Ink-Jet Printing