Istanbul Technical University Faculty of Mechanical Engineering

MAK422E Engineering Design and CAD Final Exam, Jan.4, 2005

Instructors: Hikmet Kocabas Time: 100 minutes

1. (15) Apply mirror transformation matrix with respect to x axis on triangle (Fig.1) formed by end points P_1 (2,3), P_2 (1,2), P_3 (3,1). Sketch the results.

n = (x2 - x1) / |x2 - x1|

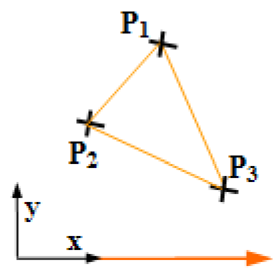


Fig.1

Answer 1. Mirror point with respect to (wrt) an axis :

$$x1 := \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \qquad x2 := \begin{pmatrix} 4 \\ 0 \\ 0 \end{pmatrix} \qquad X := \begin{pmatrix} x1_0 & x1_1 & x1_2 & 1 \\ x2_0 & x2_1 & x2_2 & 1 \end{pmatrix} \qquad X^T = \begin{pmatrix} 0 & 4 \\ 0 & 0 \\ 0 & 0 \\ 1 & 1 \end{pmatrix}$$

mirror axis

mirror wrt x axis

$$Mirr := \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

points to mirror

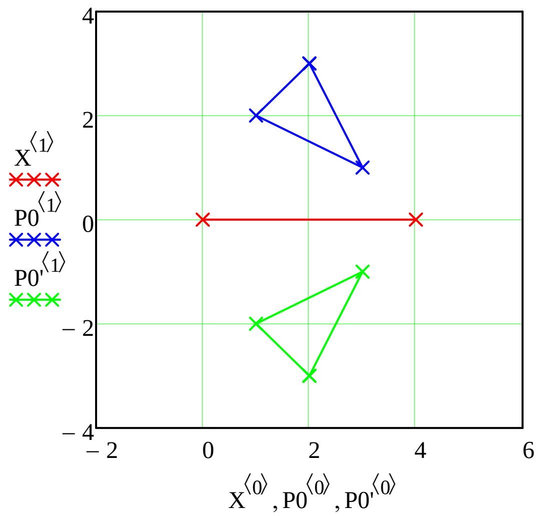
$$P0 := \begin{pmatrix} 2 & 3 & 0 & 1 \\ 1 & 2 & 0 & 1 \\ 3 & 1 & 0 & 1 \\ 2 & 3 & 0 & 1 \end{pmatrix} \qquad P0^T \rightarrow \begin{pmatrix} 2 & 1 & 3 & 2 \\ 3 & 2 & 1 & 3 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \end{pmatrix}$$

$$Rz(\theta) := \begin{pmatrix} \cos(\theta) & -\sin(\theta) & 0 & 0 \\ \sin(\theta) & \cos(\theta) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad T := \begin{pmatrix} 1 & 0 & 0 & x1_0 \\ 0 & 1 & 0 & x1_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad T1 := \begin{pmatrix} 1 & 0 & 0 & -x1_0 \\ 0 & 1 & 0 & -x1_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\theta := \operatorname{atan}\left(\frac{x2_1 - x1_1}{x2_0 - x1_0}\right) \qquad \theta = 0\,deg \qquad T \cdot Rz(-\theta) \cdot Mirr \cdot Rz(\theta) \cdot T1 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$P1 := T \cdot Rz(\theta) \cdot Mirr \cdot Rz(-\theta) \cdot T1 \cdot P0^T \qquad P1 = \begin{pmatrix} 2 & 1 & 3 & 2 \\ -3 & -2 & -1 & -3 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \end{pmatrix}$$

$$P0' := P1^T$$



2. (15) Find the tangent point P_3 (Fig.2) and radius r of circle defined by center P_0=(2,6) to line between P_1=(1,2), P_2=(7,6) ? Use vector algebra
$A \cdot B = |A|.|B|.\cos(\theta)$ $|A \times n| = |A|.1.\sin(\theta)$
Sketch the results.

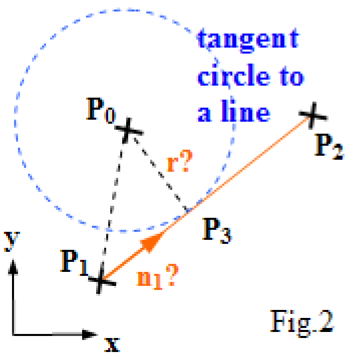


Fig.2

Answer 2. Tangent point of line and circle:

$P_1 := \begin{pmatrix} 1 \\ 2 \\ 0 \end{pmatrix}$ $P_2 := \begin{pmatrix} 7 \\ 6 \\ 0 \end{pmatrix}$ $n_1 := \dfrac{(P_2 - P_1)}{|P_2 - P_1|}$ $n_1 = \begin{pmatrix} 0.832 \\ 0.555 \\ 0 \end{pmatrix}$ $|n_1| = 1$

$P_0 := \begin{pmatrix} 2 \\ 6 \\ 0 \end{pmatrix}$ $n_2 := \dfrac{(P_0 - P_1)}{|P_0 - P_1|}$ $n_2 = \begin{pmatrix} 0.243 \\ 0.97 \\ 0 \end{pmatrix}$ $|n_2| = 1$

$(P_0 - P_1) \cdot n_1 = 3.051$ $P_3 := P_1 + n_1 \cdot [(P_0 - P_1) \cdot n_1]$ $P_3 = \begin{pmatrix} 3.538 \\ 3.692 \\ 0 \end{pmatrix}$

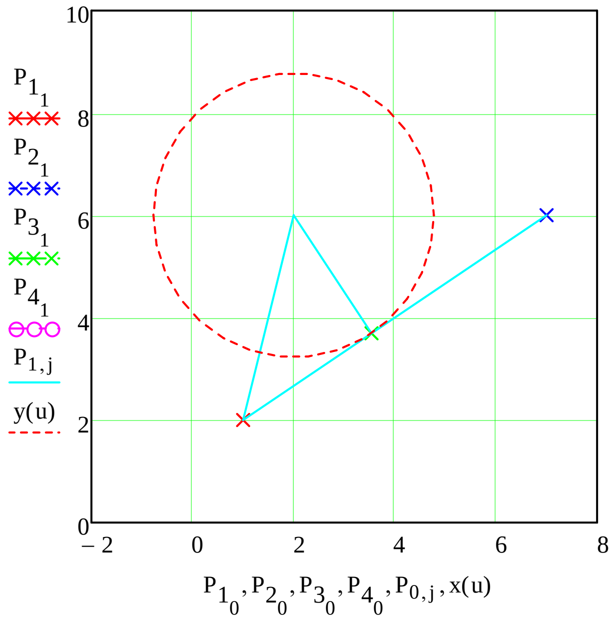
$P := \text{augment}(P_2, P_1)$ $P := \text{augment}(P, P_0)$ $P := \text{augment}(P, P_3)$ $j := 0 .. \text{cols}(P)$

$R := |(P_0 - P_1) \times n_1|$ $R = 2.774$ $|P_3 - P_0| = 2.774$

parametric form of the circle

$n := 30$ $i := 0 .. n$ $u_i := \dfrac{i \cdot 2 \cdot \pi}{n}$

$x(u) := P_{0_0} + R \cdot \cos(u)$ $y(u) := P_{0_1} + R \cdot \sin(u)$ $C(u) := \begin{pmatrix} x(u) \\ y(u) \\ 0 \end{pmatrix}$



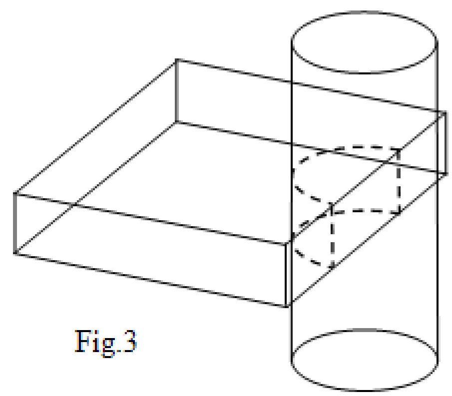
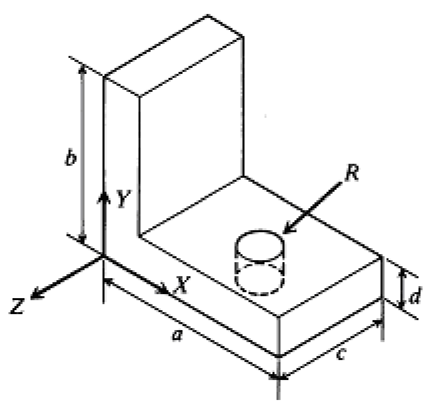
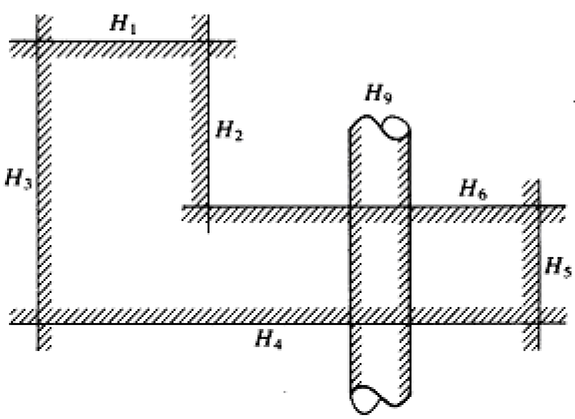


Fig.3

3. **(10)** How do you build the following Fig.3 as solid by using half-spaces?

Answer 3.





4. (10) What is difference between geometric representations and topological representations?

Answer 4. Unlike wireframe and surface models, which contain only geometric data, solid models contain both geometric data and topological information of the correspond objects. The difference between geometry and topology is illustrated in Figure 4. Geom (sometimes called metric information) is the actual dimensions that define the entities o object. The geometry that defines the object shown in Fig.4 is the lengths of lines L_1, L_2 and L_3, the angles between the lines, and the radius R and the center P_1 of the half-circl Topology (sometimes called combinatorial structure), on the other hand, is the connecti and associativity of the object entities. It has to do with the notion of neighborhood; tha it determines the relational information between object entities.

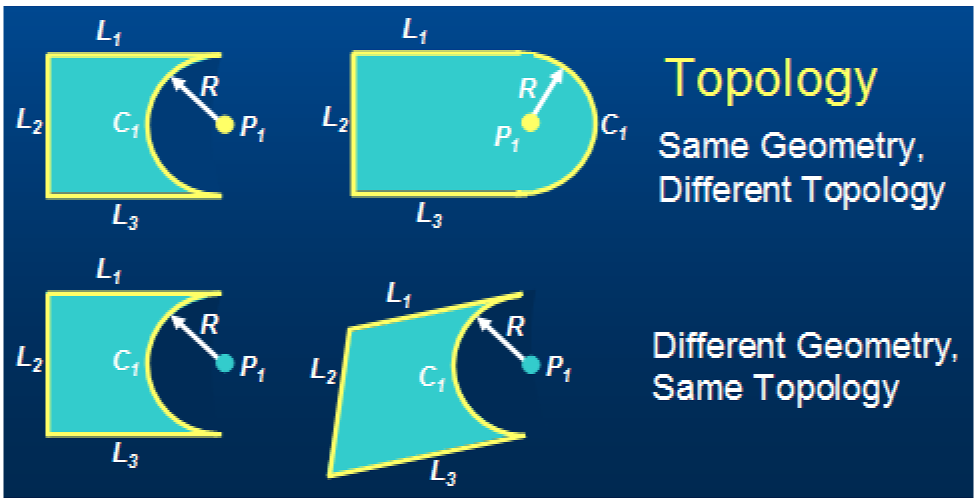


Fig. 4

5. (15) What are Design For X (DFX) acronyms?

Answer 5. Some of the DFX acronyms are, (modified from [Dodd, 1992])

DFA	Design For Assembly	DFP	Design For Portability (Software
DFD	Design For Disassembly	DFQ	Design For Quality
DFEMC	Design For ElectroMagnetic	DFR	Design For Redesign
Compatibility		DFR	Design For Reliability
DFESD	Design For Electrostatic	DFR	Design For Reuse
Discharge		DFS	Design For Safety
DFI	Design For Installability	DFS	Design For Simplicity
DFM	Design For Maintainability	DFS	Design For Speed
DFM	Design For Manufacturability	DFT	Design For Test
DFML	Design For Material Logistics		

6. (15) Write down the main principles of Design for Manufacture.

Answer 6. PRINCIPLES OF DFM

1. Reduce the total number of parts
2. Develop modular designs
3. Use standard components
4. Parts should be multi-functional
5. Parts should be multi-use
6. Parts should be designed for ease of fabrication
7. Avoid separate fasteners
8. Minimize the number of assembly directions.
10. Minimize handling

7. (10) What are the advantages of these engineering design techniques?

Answer 7. Advantages of these techniques are,

- shorter production times
- fewer production steps
- smaller parts inventory
- more standardized parts
- simpler designs that are more likely to be robust
- they can help when expertise is not available, or as a way to reexamine traditional desi
- proven to be very successful over decades of application

8. (10) How do you define a design optimization problem?

Answer 8.

- Design variables
- Design constraints
- Design function, minimization/maximization
- Iteration