IEEM 317 Product Design and Development **Name: MODEL**
Fall 2004, Exam I
Max Time 2 Hours, Max Score: 50 **SID:**

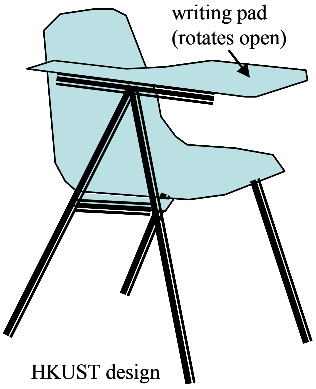
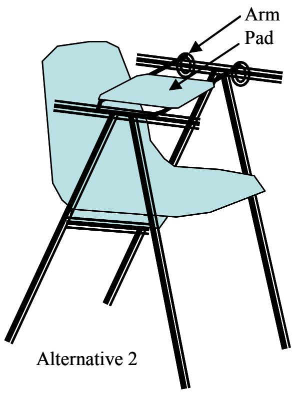
Question 1. Conceptual Design, Design evaluation ***[6+2+2]***

(i) Given below is the sketch of a typical chair used in many classrooms in HKUST. Due to the position of the writing pad, different chairs must be used by right-handed or left-handed users.

Two alternate designs are proposed in which the same chair can be used by either right- or left-handed users. Compare the two new designs against the HKUST design using Pugh's method. For each rating you give, give a reason (1-2 lines max).

(ii) Based on your answers, which is the best design?

(iii) Write one point each for SWOT analysis of the better design among the two new ones.

		
Pad rotates open to allow user to sit	Both pads can be opened to sit	Arm rotates to allow user to sit Pad can slide to left or right
Ease of sitting/getting up	(-) (i) must rotate both pads to sit (ii) cannot slide out and up from side, as in HKUST design	(-) --same as Alternative 1--
Manufacturing cost	(-) Extra pad, longer legs on left, extra assembly operations	(-) Two moving joints (rotation, sliding), longer leg on left.
Convenience of use	(+) More surface area	(+) (on average) Can be used by left- and right-handed user
Ability to Stack-up chairs	(S) Can be stacked	(S) Can be stacked, with arm and pad rotated by less than 270°

(ii) From the above, the two have same rating; further, both new designs can be very uncomfortable for fat users. Alternative 1 is perhaps a little better than Alternative 2, because (a) double moving joints on Alternative 2 may be less robust, (ii) the pad can move during use, causing potential irritation, (iii) Alternative 1 gives more surface area to keep your stuff.

SWOT:
S: Classroom can have fixed set of furniture even if % of left-handed users changes a lot.
W: More cost, not as comfortable to sit, get up, for fat users, etc.

O: high-class schools tend to have smaller class-sizes; this design may be attractive for rooms with very small number of users (since % of left-handed users can fluctuate a lot).
T: Other similar products in the market

Question 2. Product Family Design **[4+4]**

(a) *Recall that Taguchi used his "quality loss" function, $L = K(y - m)^2$, to determine the size ranges that should be offered. The 'optimal' spacing between consecutive sizes of product is such that the cost per product for the manufacturer is equal to the average loss of quality to the society.*
Assume that a manufacturer uses this method to determine three consecutive size steps for a product, and these sizes are given by: s1, s2, and s3.

State TRUE or FALSE, giving your ***reason****:*

The step sizes suggested by Taguchi's method will be equal, namely, $s2 - s1 = s3 - s2$.

In general, this is FALSE.
Reasons:
(a) Taguchi allows cost (and therefore price) for different sizes ranges to be different; hence L(y) can be different in different ranges;
(b) Population distribution and relative size of population in different ranges can be different. The net loss to society is actually computed as the $\int L(y)pdf(y)dy$, over the range, where pdf is the probability distribution function for ideal size of the demand.

[If we assume that the Loss functions _and_ the population distribution over [s1, s2] and [s2, s3] are identical, only then the condition will be true.].

(b) Pahl and Beitz's suggestion is that consecutive step sizes should be geometrically spaced, namely, s3/s2 = s2/s1. Can this guideline be consistent with Taguchi's guideline? If not, why not? If Yes, under what conditions?

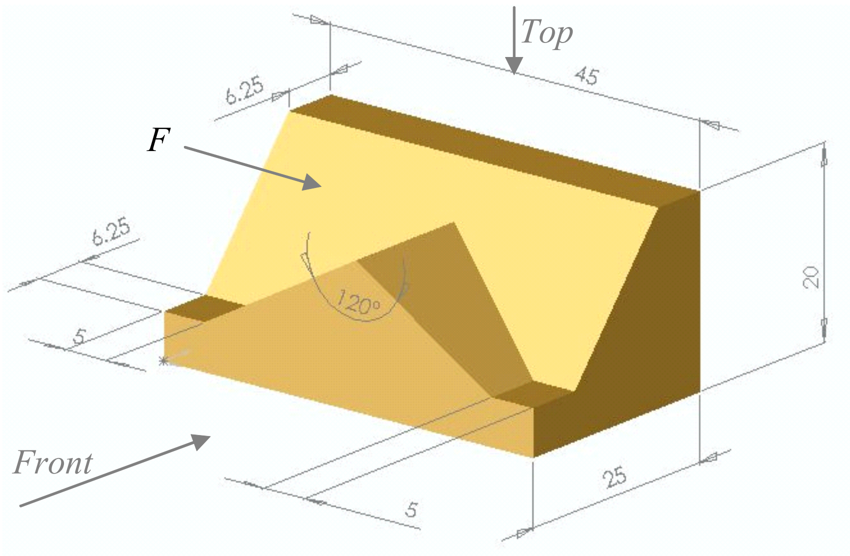
YES, the two guidelines _can_ be consistent (though they may not always be so).
It depends on the Loss function in the two size ranges, and also on the population, as discussed above.

For an ideal answer, I would expect you to write the derivation, as follows:
Using Taguchi's analysis, write the formulation for ideal sizes in terms of K1, K2, K3, K4 (the coefficients of the Loss function in the two ranges), and a generic pdf(y). solution of this system gives Taguchi step sizes, s1, s2, s3 (they will be functions of pdf(y) and the Ki). Then set s1/s2 = s2/s3.

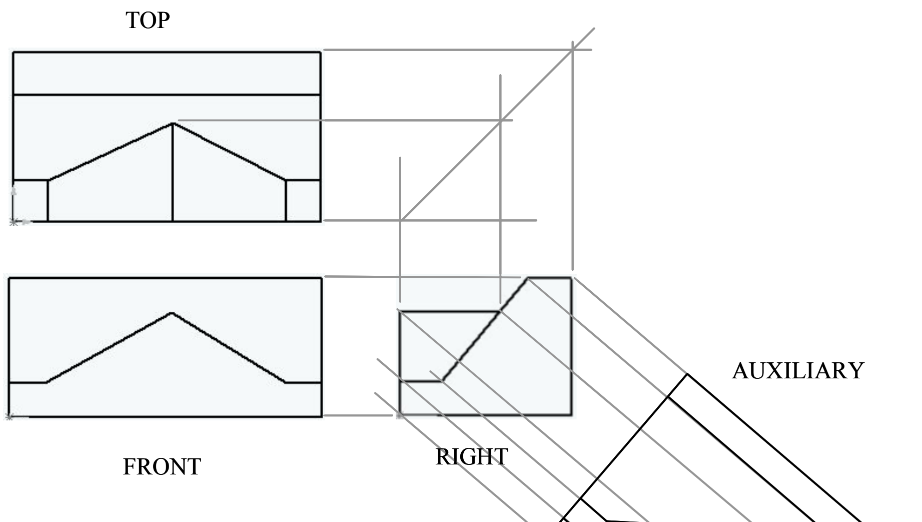
Question 3. Engineering Drawings and Projections **[(4+4)+4]**

(a)

(i) The figure below shows a symmetric mechanical part (a pivot-block); draw the following three orthographic views: TOP, FRONT and RIGHT side.

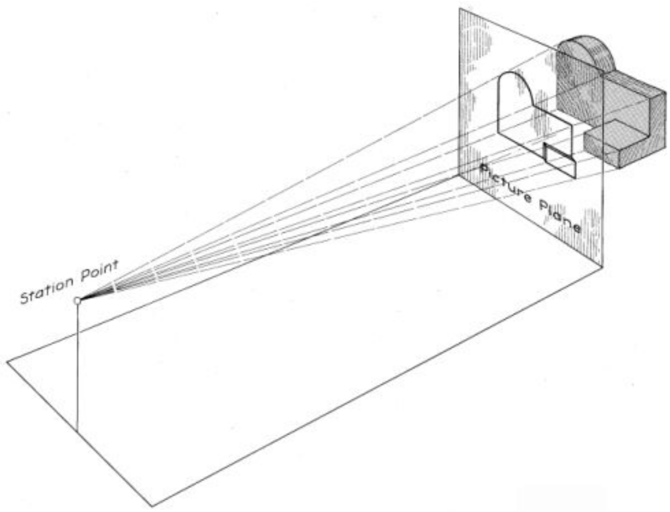


(ii) Using the orthographic views, make a projection view that shows the face marked ***F*** *in true size. This view must show all faces that are visible in the TOP view of the part.*



NOTES:
(i) Face F will be in TRUE size in an orthographic project normal to F
(ii) Face F appears as an edge in RIGHT
(iii) Projection lines used to draw AUXILIARY view are normal to Face F in the Right view.

***(b)** Consider a perspective image of an object where (i) the object is completely behind (and not touching) the picture plane, and (ii) the station point (viewing point) is at a finite distance from the picture plane (see image below). Is it possible for any face of the object to appear in true size? If yes, show an example; if not, prove your answer.*



(1) If any face that is completely behind the picture plane will appear in true size, then every line on this face must appear in true size.

(2) Consider an arbitrary line joining [x1 y1 z1] and [x2 y2 z2]; its length =
L = SQRT(((x1 – x2)^2 + (y1 – y2)^2 + (z1 – z2)^2)

(3) What are the coordinates of these points on the picture plane ? for convenience, place a coordinate frame with origin at the station point, and Z-axis along the normal to the picture plane.

Let the distance of the Station point to the picture plane = s;

Let the coordinates of the perspective projection of [x1, y1 z1] be [x1' y1' z1'] and the coordinates of the perspective projection of [x2, y2 z2] be [x2' y2' z2'].

Draw a figure for this situation, and convince yourself (using similar triangles), that:

x1' = x1 (s/z1), y1' = y1 (s/z1), and z1' = s
and
x2' = x2 (s/z2), y2' = y2 (s/z2), and z2' = s.

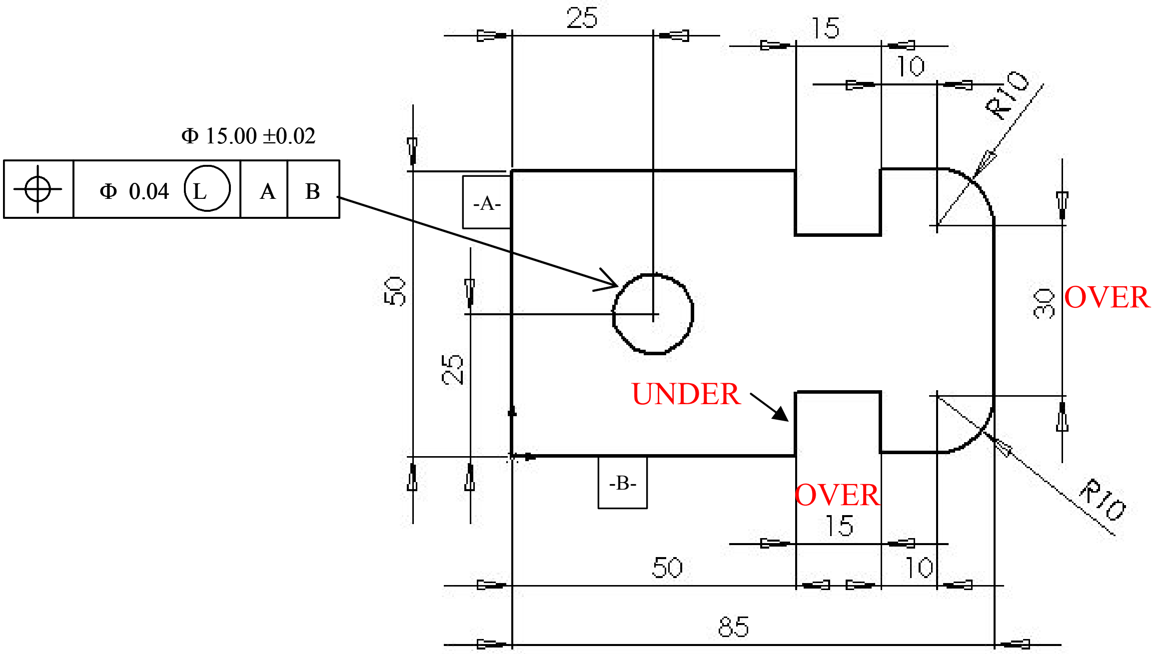
Note that s/z1 and s/z2 < 1, and both are positive; thus |x1'| < |x1|, |y1'| < |y1'|, etc.

The length of the projected line is SQRT((x1' – x2')^2 + (y1' – y2')^2) = L'

Using above and some algebra, you can now prove that L' < L.

Question 4. Dimensioning and Tolerancing **[(2+4+2)+(2+2)]**

(a) *The following figure shows an engineering drawing for a simple part.*

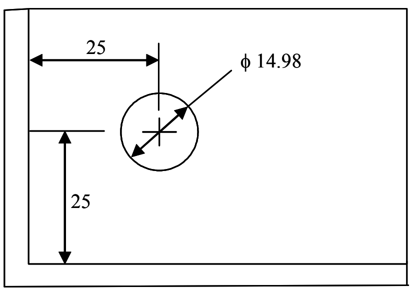


(i) Among the dimensions on the drawing, identify and mark one example of over-dimensioning, and one example of under-dimensioning. Give reason for your answer (one line max, for each case).

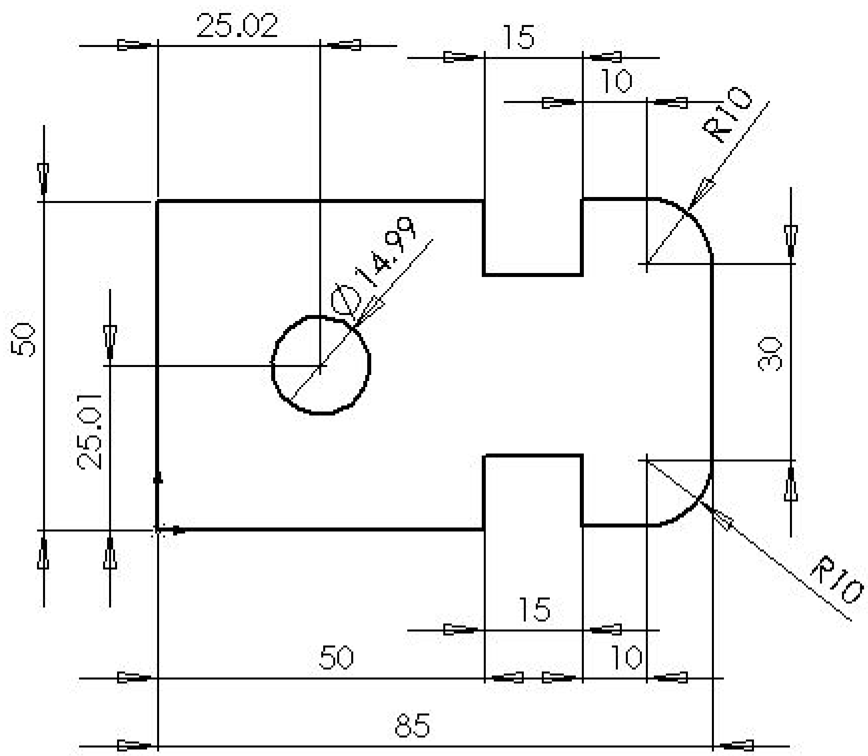
Over-dimensioning:
Length 30 can be determined as 50 – 10 – 10.
width of slot can be determined from 85 – 50 – 10 – 10 = 15.
Under-dimensioning:
Height of slot cannot be determined, and is not specified.

(ii) Sketch the top view of a gauge that can be used to check the location of the hole, showing the important sizes and dimensions.

At LMC, hole size = 15.02; since its center can be located anywhere in a circle centered at (25, 25), and with diameter = 0.04, therefore the gauge pin diameter must be: 15.02 – 0.04 = 14.98. [Please see model solution of Assignment to understand why].



(iii) Does the hole in the part shown below meet the specifications of the drawing (give reason)?



Limits on hole size are [14.98, 15.02], so the size of the hole in the above part is OK.

However, its center is at a distance [0.01 0.02] away from the nominal position, which is outside the TRUE position tolerance zone. The TRUE position tolerance zone is a circle of radius 0.02 around the ideal center point at (25, 25).

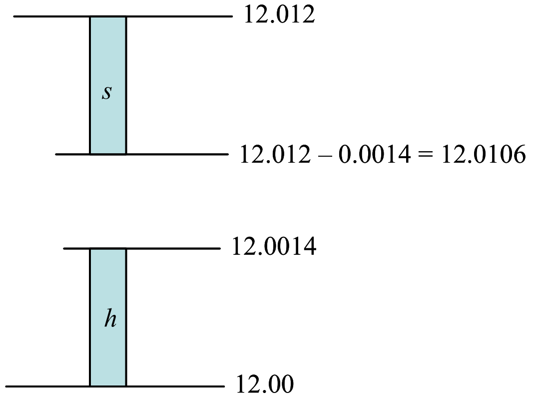
Further, the hole itself is smaller than LMC (since 14.99 < 15.02); for LMC tolerances, the actual tolerance of position of hole center will decrease as the hole size gets smaller than LMC size. Hence, this part has a hole center that will definitely fall outside its allowed tolerance zone. The part will be rejected.

(b) *In a motorcycle engine design, the rocker-arm is connected to the piston by a pin. The pin has a nominal diameter of 12 mm, and is inserted into the hole in the piston with a shrink fit.*

(i) What are the recommended tolerances on the hole and shaft sizes? What is the allowance for the required fit?

(ii) Using the hole basic convention, sketch the tolerance zones for the hole and shaft, clearly marking the values for tolerances and allowance.

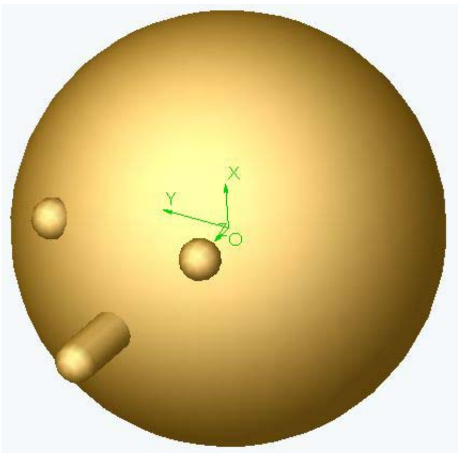
From ANSI fits chart, and nominal dia = d = 12mm,
Allowance, a = -0.001d = -0.012mm
Shaft, hole tolerances are s = h = $0.0006d^{1/3} \approx 0.0014$mm



Question 5. CAD Modeling **[8]**

For the doll-head shown in the figure below, write each step you would use to make its CAD model using Solidworks. The steps must be shown in the correct sequence, and for each step:

- *If a sketch is required (or multiple sketches are required for that step), show each sketch and dimensions;*
- *The operation you will use, and the parameters you will need.*



Geometric details for the construction:
(i) The 'head' (big sphere) is centered at the origin, with diameter = 100mm.
(ii) The 'nose' is a cylindrical surface along the Z-axis; its diameter is 10mm, and at its end is a spherical surface of diameter 10mm. The cylindrical part of the nose has a length of 15mm.

(iii) The 'eyes' are spherical surfaces with diameter 10mm; the center point of each 'eye' lies on the surface of the 'head', and is 20mm above the YZ plane, and 20mm away from the XZ plane.

[There are several ways to solve this, below is just one]

Step 1. Sketch a square of side 100mm on Front plane
Step 2. Extrude the square by 100 mm keeping the Front plane a the middle plane
Step 3. Open a new sketch on Front plane, and make a semi-circle centered at origin, radius = 50; also draw an axis-line joining the end points of the semi-circle
Step4. Insert a surface by revolving this sketch by 360° around the axis
Step5. Insert a cut-with-surface to remove all region of square box outside the spherical surface, to get the head.

[NOTE: Alternatively, make a ϕ100, h=100 cylinder, and put 50mm fillets on both its end faces]

Step6. Open a new sketch on the XY plane, and draw a circle ϕ10mm, center on the origin.
Step7. Extrude the circular sketch by 100 mm in one direction; (should be longer than the total length of the nose).
Step 8. Open a sketch on the YZ plane, and draw the profile of the front part of the nose: A semi-circle with center on the Z axis, and the two end points coincident with the top- and bottom-edges of the nose-cylinder's profile. [Note: use a silhouette function, e.g. convert-entities or insert split-line, if necessary]. Set the distance of the end point to the profile of the sphere as 12mm. Draw an axis line along the diameter of the semi-circle.
Step9. Insert the front surface of nose (semi-sphere) by revolving the semi-circle profile by [-90°, +90°]; cut the long nose cylinder with this surface to create the nose.

Step11. To find location of center of left eye, create axis-parallel planes: the first is offset 20mm (towards +X direction) from the YZ-plane, and the second is offset from the XZ-plane by 20mm to left.
Step12. Open a sketch in either of these two planes; draw a semi-circle with radius=10mm, and center is coincident on the intersection point of the spherical surface and the two offset planes. Draw a diameter-axis line for the semi-circle
Step13. Insert a spherical surface for the left eye by revolving the semi-circle by 360° around the axis (you may have to fill the surface with a solid);
Step14. Mirror the left eye about the YZ plane to get the right eye.
DONE.

Notes that may be useful

ANSI fit classification.

FIT	Sub-Type	***a*** (allowance)	***h*** (hole tolerance)	***s*** (shaft tolerance)
Clearance [easy assembly, may vibrate in use]	Loose	$0.0025d^{2/3}$	$0.0025d^{1/3}$	$0.0025d^{1/3}$
	Free	$0.0014d^{2/3}$	$0.0013d^{1/3}$	$0.0013d^{1/3}$
	Medium	$0.0009d^{2/3}$	$0.0018d^{1/3}$	$0.0018d^{1/3}$
Transition [difficult to mfg precision fit	Snug	0	$0.0006d^{1/3}$	$0.0004d^{1/3}$
	Wringing	0	$0.0006d^{1/3}$	$0.0004d^{1/3}$
Interference [difficult assembly can transmit torque]	Tight	$-0.00025d$	$0.0006d^{1/3}$	$0.0006d^{1/3}$
	Medium Force	$-0.0005d$	$0.0006d^{1/3}$	$0.0006d^{1/3}$
	Shrink	$-0.001d$	$0.0006d^{1/3}$	$0.0006d^{1/3}$

(assume that d is in mm)