2006 MET 1 P1 Dr W O'Neill

MANUFACTURING ENGINEERING TRIPOS PART I

Saturday 29 April 2006 9 to 12

PAPER P1

DESIGN AND MANUFACTURE

Answer not more than ***four*** *questions of which not more than* ***one*** *may be taken from each section* ***A, B, C*** *and* ***D****.*

Answers to sections ***A, B, C*** *and* ***D*** *must appear in four separate booklets.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Crib

STATIONERY REQUIREMENTS

8 Page Answer Book x 4

Rough Work Pad

SPECIAL REQUIREMENTS

Engineering Data Book

P1 Data Book

ATTACHMENTS

If you choose to answer QUESTION THREE, the two attachments contained in this paper should be attached firmly to your answer booklet. Write your candidate number on each of the attachments and annotate them with your answer to the question.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

SECTION A

*Answer **one** question from this section.*

1 (a) Name the four characteristics of an optimised design. [10%]

(b) When designing for optimised assembly, explain what 'design efficiency' means. Outline how you might analyse an existing design in order to reduce the number of components and list the nine questions you might use to help you do this.

[15%]

(c) The design shown in Figure 1 is an old design for the front mechanism of a hand-held power saw. Not shown is the motor with a gear wheel on its shaft, which enters the hole at the right hand end of the housing, meshing with and turning the gear. The pin on the gear links with the connecting rod which links with the piston via another pin, converting the rotary motion of the gear to a reciprocating motion for the saw blade. Make a preliminary list of what you consider might be primary components and estimate the design efficiency. [25%]

(d) Sketch and explain a simplified design focusing on the primary functionality, adding features to the primary components and minimising the number of secondary components to reach a design efficiency of at least 60%. Apply the four key questions to the mechanism as a whole and describe the essential functions that will have to be fulfilled by such a mechanism.

[50%]

(cont

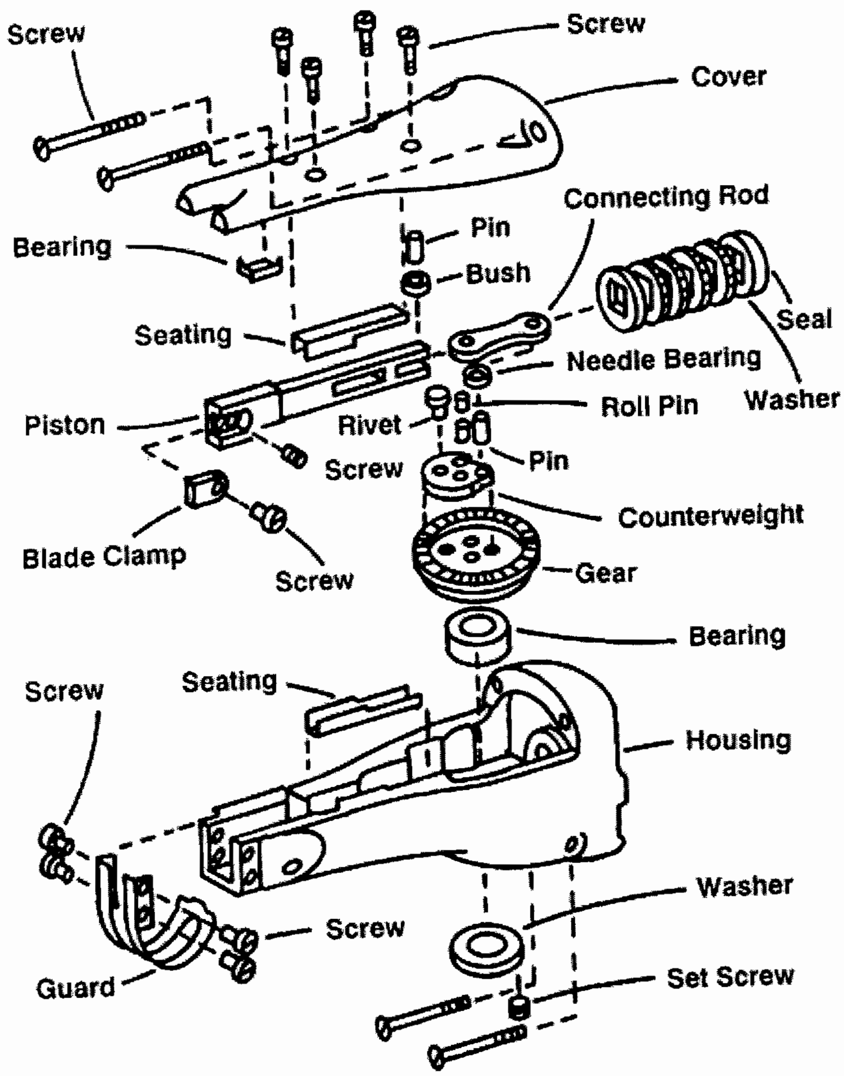

Screw
Screw
Cover
Connecting Rod
Pin
Bearing
Bush
Seal
Seating
Needle Bearing
Washer
Roll Pin
Piston
Rivet
Screw
Pin
Counterweight
Blade Clamp
Gear
Screw
Bearing
Screw
Seating
Housing
Washer
Screw
Set Screw
Guard

Figure 1

2 (a) Briefly outline the Fisher/Deming/Taguchi story and explain the philosophy underlying the Taguchi approach to quality control. [15%]

(b) Explain the principle behind the design of a set of Taguchi experiments and outline how information on the effect of each parameter being investigated can be extracted from the results. [15%]

(c) In the commissioning of a poly-silicon deposition process, the settings of six out of the eight control parameters are being explored, with the intention of maximising the deposition rate whilst minimising the number of surface defects. The remaining two control parameters are considered to have a negligible effect but have been included as dummy parameters marked 'x' in the experiments. The six parameters being explored are each given three settings as outlined in Table 1. Eighteen tests are conducted and the settings for each parameter and the resulting levels of surface defects and rates of deposition are recorded in Table 2. Using the conventional quadratic loss function, the defect and deposition rates are converted into decibel levels, so that

Defect level (dB) $= -10 \log_{10}(\text{surface defect count})^2$

Deposition rate (dB) $= +10 \log_{10}(\text{deposition rate})^2$

Calculate and plot the effects of the settings of the six parameters being studied in these experiments. [50%]

(d) Discuss the effects of the different parameters and suggest a strategy for maximising overall production rate, given that significant surface defects cause rejection of the element produced before it is passed to the next process. [20%]

(cont

Factor	Levels		
	1	2	3
A. Deposition temperature (°C)	T_o - 25	T_o	T_o + 25
B. Deposition Pressure (mtorr)	P_o - 200	P_o	P_o + 200
C. Nitrogen flow (sccm)	N_o	N_o - 150	N_o - 75
D. Silane flow (sccm)	S_o - 100	S_o -50	S_o
E. Settling time (min)	t_o	t_o + 8	t_o + 16
F. Cleaning method	None	CM_2	CM_3

Table 1

Table 2

Expt No.	Experiment settings								Defect Level (dB)	Deposition Rate (dB)
	x	A	B	C	D	E	x	F		
1	1	1	1	1	1	1	1	1	0.51	23.23
2	1	1	2	2	2	2	2	2	-37.30	31.27
3	1	1	3	3	3	3	3	3	-45.17	32.34
4	1	2	1	1	2	2	3	3	-25.76	31.15
5	1	2	2	2	3	3	1	1	-62.54	37.27
6	1	2	3	3	1	1	2	2	-62.23	33.89
7	1	3	1	2	1	3	2	3	-59.88	37.68
8	1	3	2	3	2	1	3	1	-71.69	40.46
9	1	3	3	1	3	2	1	2	-68.15	41.21
10	2	1	1	3	3	2	2	1	-3.47	27.89
11	2	1	2	1	1	3	3	2	-5.08	26.02
12	2	1	3	2	2	1	1	3	-54.85	31.82
13	2	2	1	2	3	1	3	2	-49.38	34.50
14	2	2	2	3	1	2	1	3	-36.54	33.20
15	2	2	3	1	2	3	2	1	-64.18	34.76
16	2	3	1	3	2	3	1	2	-27.31	37.71
17	2	3	2	1	3	1	2	3	-71.51	40.45
18	2	3	3	2	1	2	3	1	-72.00	39.22

SECTION B

*Answer **one** question from this section.*

3 You are the chief engineer in a precision engineering firm. A trainee has given you a component drawing to check – the part is a spindle housing – and is named 'Exam 1'.

(a) Looking at the drawing provided in Figure 2, describe the way in which this part will be made in production, starting from raw material and including every subsequent processing step, describing any tooling, fixtures or gauging that may be required.

[25%]

(b) The drawing in Figure 2 needs significant improvement. On *'Sheet 1'* (*provided as an attachment*), mark up the drawing, identifying all of the errors, ambiguities and improvements needed. Your notes should be written *on* the attachment, along with your candidate number.

[25%]

(c) The trainee has missed two important dimensions – diameter C and diameter D, but has described the type of fit needed. Diameter C requires a tight transition fit of nominal size ∅86.0 mm, and diameter D requires a loose clearance fit of nominal size ∅41.5 mm. Calculate the appropriate tolerances for these two features.

[10%]

(d) As chief engineer, you have decided that Diameters C and D also require further geometric tolerances to ensure functionality. On *'Sheet 2' (provided as an attachment)*, add appropriate geometrical tolerances, to ensure that these two features are concentric to each other, and are perpendicular to the front surface of the component. Your answer should be written *on* the attachment, along with your candidate number.

[20%]

(e) You also prefer to see all drilled holes dimensioned using positional tolerances. Also on *'Sheet 2'*, demonstrate how the 16 M5 holes and the 8 holes for M6 bolts should be specified using positional tolerancing. Your answer should be written *on* the attachment, along with your candidate number.

[20%]

(cont

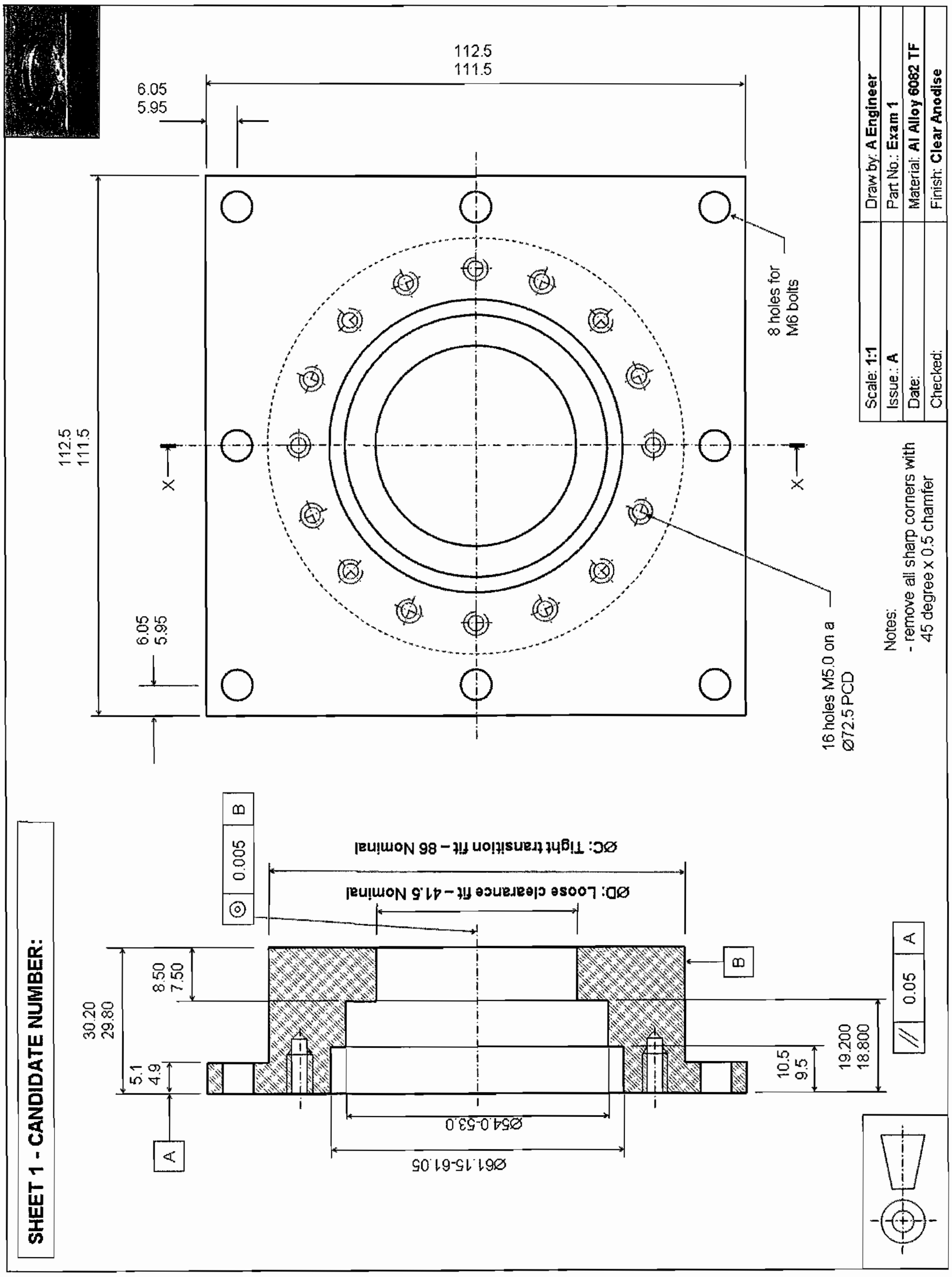

SHEET 1 - CANDIDATE NUMBER:
112.5
111.5
6.05
5.95
8 holes for M6 bolts
16 holes M5.0 on a Ø72.5 PCD
X
X
ØC: Tight transition fit – 86 Nominal
ØD: Loose clearance fit – 41.5 Nominal
0.005 B
B
A
30.20
29.80
8.50
7.50
5.1
4.9
10.5
9.5
19.200
18.800
0.05 A
Ø54.0-53.0
Ø61.15-61.05
Notes:
- remove all sharp corners with 45 degree x 0.5 chamfer
Scale: 1:1
Issue.: A
Date:
Checked:
Draw by: A Engineer
Part No.: Exam 1
Material: Al Alloy 6082 TF
Finish: Clear Anodise

Figure 2

4 You are a production manager in a firm that makes extruded components. To reduce waste and improve quality, the design office wishes to tighten the tolerance on the length of a critical component. 1000 parts from the first batch of the day have been measured, resulting in a mean length of 255.1 mm and a standard deviation of 0.7 mm.

(a) Calculate a sensible Upper Specification Limit (USL) and Lower Specification Limit (LSL) for a single component and explain your reasoning. [5%]

(b) Throughout the rest of the day, a further five batches of parts are measured. The mean and standard deviation are calculated for a sample of 1000 for each batch as shown in Table 3. For each batch, calculate the Cpk value, using your answers from part (a) for the LSL and USL values. [35%]

Table 3 Mean and standard deviation for each batch of 1000 components, all dimensions in mm

	Morning			Afternoon		
	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6
Mean values	μ_1=255.1	μ_2=256.3	μ_3=257.0	μ_4=255.0	μ_5=256.1	μ_6=256.8
Standard deviations	σ_1=0.7	σ_2=0.6	σ_3=0.4	σ_4=0.35	σ_5=0.3	σ_6=0.25

(c) Discuss, with sketches where appropriate, what the Cpk, mean and standard deviation values might indicate about the production process and how it might be improved. [35%]

(d) Based on evidence from the whole day's production, calculate a new LSL and a new USL to recommend to the design office. [10%]

(e) The design office has responded with a desired USL of 254.6 mm and a desired LSL of 253.4 mm. As production manager, how would you respond to their request? [10%]

(f) Briefly discuss how the underlying principles of six sigma develop the concept of process capability further. [5%]

SECTION C

*Answer **one** question from this section.*

5 (a) For a production facility discuss the differences between a functional layout and a cellular layout. Identify the advantages and disadvantages of each layout.

[40%]

(b) A company manufactures five product groups as shown in Table 4, (A, B, C, D, E, and F are functional departments).

Product Group	Production Sequence	Production/Week
Hays	ABCDEF	2000
Bees	DBCAF	3500
Sees	CADAFA	6000
Dees	FECDBC	2500
Ease	CBDECAB	500

Table 4

i) Using this data, create an activity relationship diagram. [30%]

ii) Describe in detail what other data you would require to enable you to develop a factory layout, and discuss the stages that you would go through to do this.

[30%]

6 (a) Define the term 'method study'. Briefly outline the main stages of method study. [30%]

(b) As part of a study into the machining operations in a production department you wish to know the utilisation of five machines. The foreman has estimated that three machines have a utilisation of 80%, one has a utilisation of 70% and one a utilisation of 50%. You decide to verify his estimates by means of an activity sampling study. Describe in detail how you would design and carry out the study, assuming that you wish to be 90% confident that the error in the values you determine would be no greater than +/- 5% in absolute terms (e.g. if the estimate were 78%, you wish to be 90% certain the true value lies between 73% and 83%). [50%]

(c) Discuss the advantages and disadvantages of activity sampling compared to time study. [20%]

SECTION D

*Answer **one** question from this section.*

7 (a) High accuracy mould tools are critical for the production of precision plastic mouldings. Name three materials that could be used for injection mould tooling and state the reasons for choosing them. [15%]

(b) Electric Discharge Machining (EDM) is an advanced machining process used for the production of complex mould tools.

(i) Describe in detail the physical principles of the EDM process and its practical implications with regard to the following:

- electrode materials;
- user selectable process parameters;
- the types of materials that can be machined;
- the importance of fluid delivery.

[50%]

(ii) What influence does energy density have on the quality of the machining?

[15%]

(c) Briefly describe two processes that are not based on mechanical cutting and can compete with EDM for the production of precision tooling. [20%]

8 (a) Machining is a general term used to describe the removal of material from a workpiece. It covers several processes which can be divided into the following categories:

(i) cutting;

(ii) abrasive processes;

(iii) advanced machining processes.

List four machining processes for each category. [12%]

(b) Describe the basic model of chip formation in an orthogonal cutting operation. Support your description with a diagram and highlight the important features of the chip formation process. [30%]

(c) The types of chip produced in a cutting operation significantly influence surface condition, machining integrity and the overall cutting operation. There are some deviations from the ideal model. Describe the four basic chips produced in metal-cutting operations, and discuss the conditions under which they are likely to occur. Use diagrams to support your answer. [28%]

(d) Consider the face milling example shown in Figure 3. The workpiece moves into the cutter at a velocity, v; the width of the cut, w, is 25 mm; the depth of cut, d, is 2.5 mm; the diameter of the cutter, D, is 50 mm; the number of cutting teeth, N, is 4; the feed per tooth is 0.175 mm; the cutter's tangential surface speed is 12,500 mm/s; and the specific cutting energy of the material is 1.1 J mm^{-3}. Calculate the following:

(i) Material Removal Rate MMR ($mm^3\ s^{-1}$)

(ii) Power requirement P (W) [30%]

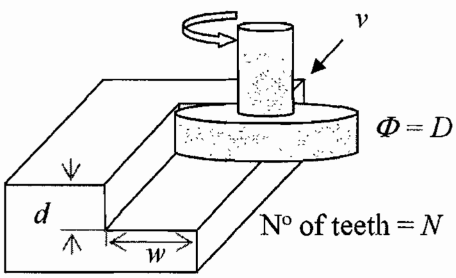
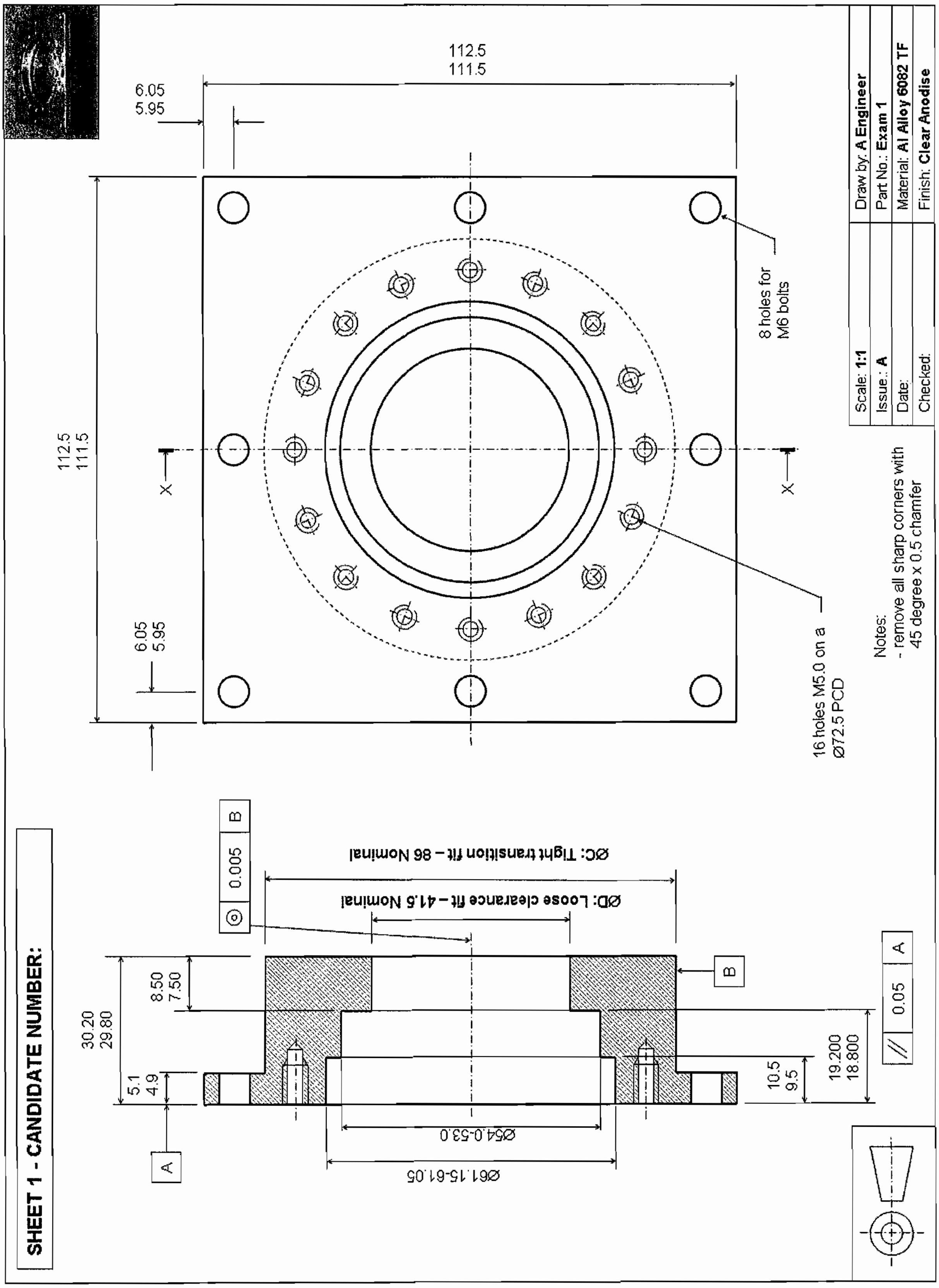
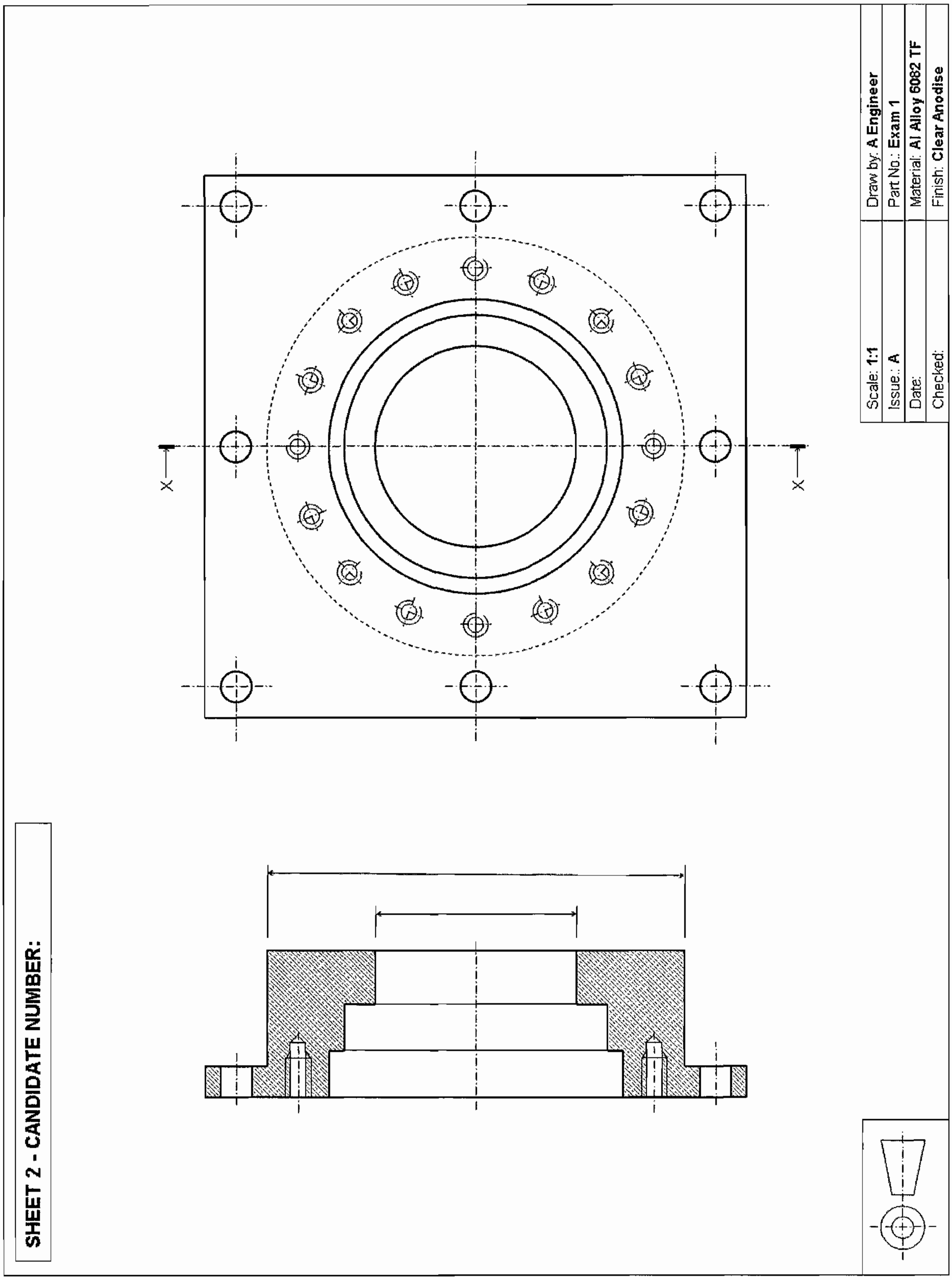


Figure 3

END OF PAPER


SHEET 1 - CANDIDATE NUMBER:
112.5
111.5
6.05
5.95
8 holes for M6 bolts
16 holes M5.0 on a Ø72.5 PCD
X
X
Draw by: A Engineer
Part No.: Exam 1
Material: Al Alloy 6082 TF
Finish: Clear Anodise
Scale: 1:1
Issue.: A
Date:
Checked:
Notes:
- remove all sharp corners with 45 degree x 0.5 chamfer
ØC: Tight transition fit – 86 Nominal
ØD: Loose clearance fit – 41.5 Nominal
0.005
B
0.05
A
30.20
29.80
8.50
7.50
5.1
4.9
10.5
9.5
19.200
18.800
Ø54.0-53.0
Ø61.15-61.05


Draw by: A Engineer
Part No.: Exam 1
Material: Al Alloy 6082 TF
Finish: Clear Anodise
Scale: 1:1
Issue.: A
Date:
Checked:
X
X
SHEET 2 - CANDIDATE NUMBER:

P1 Q's Crib 2005/6

Q1

a) Minimum mechanism (dynamic functionality)
Minimum material (static functionality)
Minimum energy content (sustainable functionality)
Minimum manufacturing process steps (For something which is assembled, it is usually considered to be minimum parts count, leading to minimum assembly steps. Sometimes thought of as minimum adjustability.)

b) When examining components it is possible to distinguish in a preliminary way those apparently doing a primary task from those apparently doing only a secondary task.

If these are designated primary and secondary components, the **design efficiency** is the number of primary components as a percentage of the total number of components.

In examining components in sequence, it is possible to ask of each component in turn:-

Does this part move relative to all the parts which have already been analysed?
Is the movement essential for the product to function?
Must the part be separate for the product to function?

Is this a part of a different material to all parts already analysed?
Is a different material essential for the product to function?
Must the part be separate to satisfy the different material requirement?

Is the part separate to allow for adjustment or replacement?
Is the adjustment or replacement essential?
Must the part be separate to enable the adjustment or replacement?

c) There are 41 parts. The primary parts might be:-

Housing
(Bearing)?
Gear
Connecting rod
Piston
(Bearing)?
Blade clamp
Cover

If this was possible (8 parts), it would give a current design efficiency of 19.5%. It might be possible to get rid of the two bearings, running the gear and piston directly in the housing, if the material combination (perhaps with surface coatings) is appropriate. That would then be six parts and a current design efficiency of 14.6%

d) In a more efficient design, the housing would be fairly similar, but the bearings might be integrated into it, as shown, and it might be shaped to allow the cover to be a snap fit onto it..

The bearing for the gear might be similar, or the gear might run in the housing, as shown.

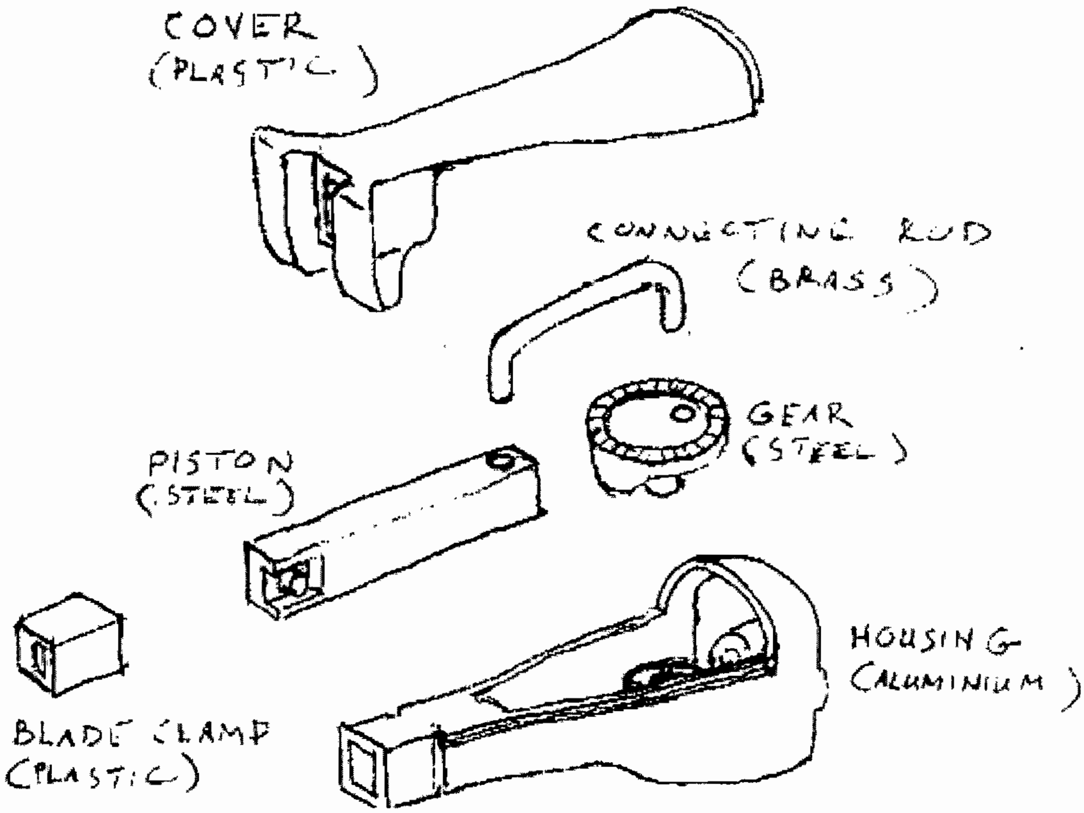
The gear wheel might have the counterweight integrated and have the hole for the pin developed as a bearing hole, as shown.

The connecting rod can be a relatively thick bent rod, thus itself being the pins at each end, as shown.

The piston can simply be a rectangular block, riding in a rectangular section bearing or directly in the housing as shown, with a simple hole for the connecting rod to pin into it at one end and a locating socket to house the saw blade at the other, located tightly in a groove and on a pin as shown.

The blade clamp can be a surrounding plastic sheath which wedges on and snaps into place and clamps the blade tightly on to the locating pin and in its groove.

The cover can be a plastic moulding as shown, which slides on from the front and locates on a lip at the back and round the sides, providing a holding down face which will prevent the connecting rod from lifting out of the gear and piston. The front of the cover forms a sheath which fits tightly round the front of the housing and snaps into place, and holds the bearing in place. The mounded front of the cover also forms the guard.



Note:- There are two posiblr approaches to this question. A confident designer will "read" the design presented and understand the intended functionality. (The essential functionality is described in the wording of the question.) They will then create a design which embodies that functionality in an efficient way. The weaker approach, which a less confident person might take, is to sequentially analyse the existing design, component by component and set out to simplify it incrementally. This will certainly improve the design efficiency but will rarely achieve the radical improvements that a complete rethink will achieve. The difference between the two approaches is that the first goes directly to the fundamentals and the second does not. The difference demonstrates the degree of fluency of the designer in design "language" (the ability to "read" it and "write" it fluently, or simply the ability to analyse it step by step using a dictionary). Good engineering design is abour clarity and succinctness of expression of functionality and the design efficiency achieved in a design is a good measure of this.

Q2

a) Fisher was an agricultural researcher at Rothamsted in the 1930s who focused on using the few parameters a farmer has (choice of type of wheat, time of planting, fertilising etc.) to survive the variations in the weather and soil which he is unable to control. Deming was an agricultural statistician in the USA in the dust bowl period in the 1930s and tried to apply Fisher's understanding to the devastating conditions in American agriculture in that decade. When he went to Japan he took with him the understanding that you only had control over small variables and the large variables you had no control over. Thus he established an approach to Quality control which is in many respects the reverse of Taylor's, where you are inclined to think you are in control of what goes on in a factory and call what you do "scientific management". Taguchi put statistical method to the thinking Deming introduced and created an approach to quality control which is based on reducing "noise" in the system, so that machines are working in their most stable ranges and the whole system is robust against uncontrolled variation. Taguchi met Fisher in India during a sabbatical year and completed his understanding and development of the statistical method.

b) In a set of Taguchi experiments, each parameter being investigated moves between an agreed number of settings (for instance 3 settings) at the same time as variations are being explored in the other parameters. However, the combinations of factor settings is so organised that, if all the readings are added up for when parameter 1 is at setting 1, it will be found that all the other parameters have been at each of their settings an equal number of times, so that on average they have a neutal effect. If the sum of these readings is taken, and divided by the number of readings, to take an average, it will be different from the overall average reading (in which all the parameters have been at each of their settings an equal number of times) only because of this one difference in the setting of parameter 1. Thus the variation from the mean due to this setting can be deduced. If this is done for all the settings of all the parameters, a complete picture of the settings explored is created and can be used to set the parameters at their most productive settings.

c) The results are:-

e.g. for factor A at setting 1 the defect level value is the average of the six values taken with A at this setting (experiments 1,2,3,10,11,12):-

$(0.51 - 37.3 - 45.17 - 3.47 - 5.08 - 54.85) / 6 = - 24.23$

Question 3: answers

a)

A good answer will describe each step in the production process, starting from Raw Material:

a. *Raw material: start from either square stock Aluminium Alloy 8062 TF, 110x110x25 deep. Or possibly start from cylindrical stock approx* ∅150 x 25 deep

b. *Square off: block out square 102 x 102*

c. *Back face: end mill 'back face' (i.e. face that does not remain square)*

d. *Front face: end mill 'front face' (i.e. face that remains square) to within 0.1mm for later finishing*

e. *Drill: drill pattern of ∅8mm holes through*

f. *Drill & Tap: pattern of M5 holes to depth*

g. *Grind front face to achieve a precise flat surface for location*

h. *Turning: hold against 'back face' and turn diameters ∅65 ∅*64

i. *Rough turn* ∅59.6 to leave approx 0.2mm for later finishing

j. *Turn around & hold flat against front face – to ensure perpendicularity of diameters C and D. Ensure the component is centred,*

k. *Finish turn ∅59.6 and ∅82.0.*

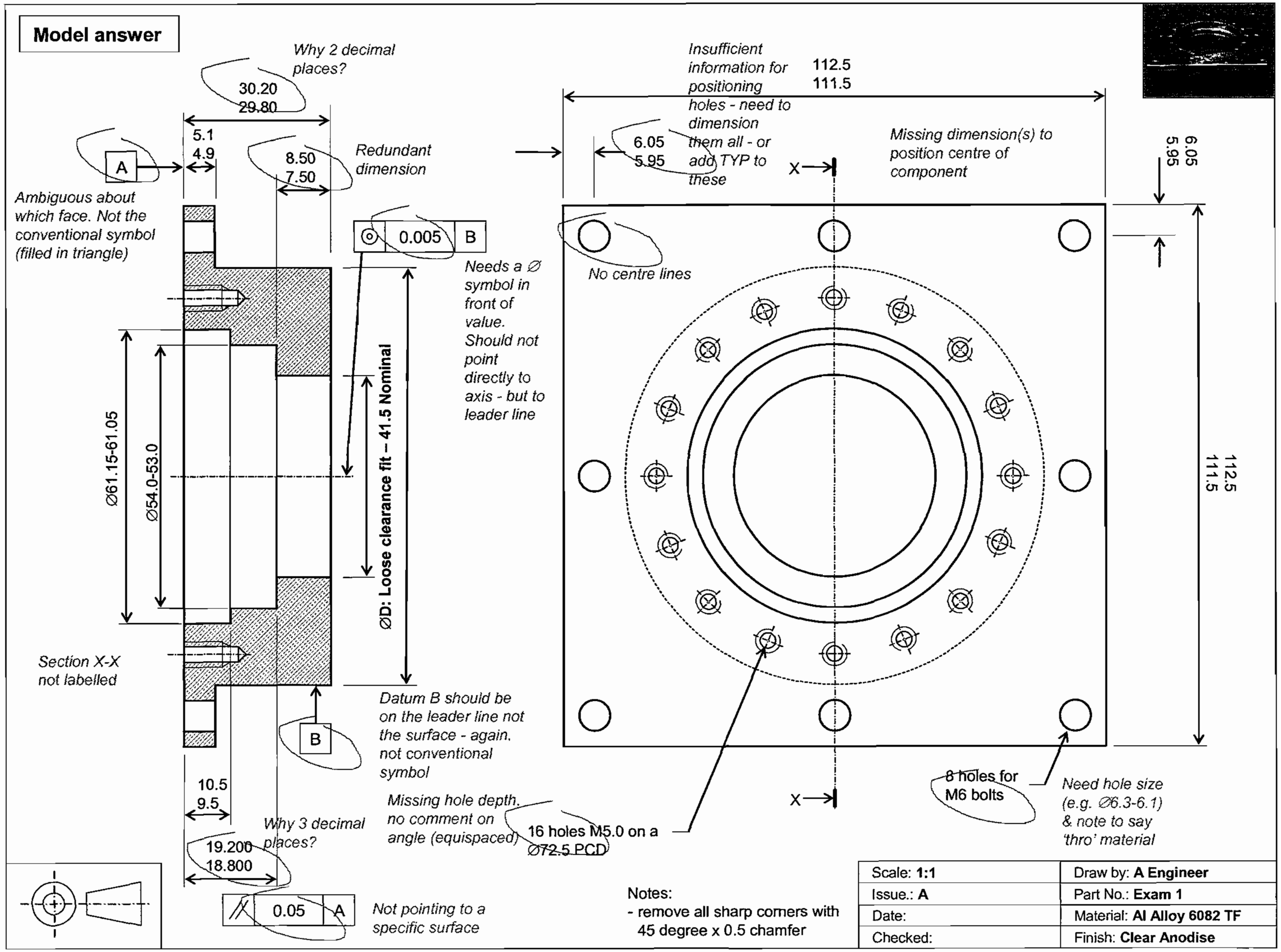
l. *Deburr & remove sharp corners*

m. *Inspection: Will need plug gauge or CMM to check ∅59.6. Can check ∅82.0 with CMM or accurate micrometer*

n. *Send for finishing – Clear anodise*

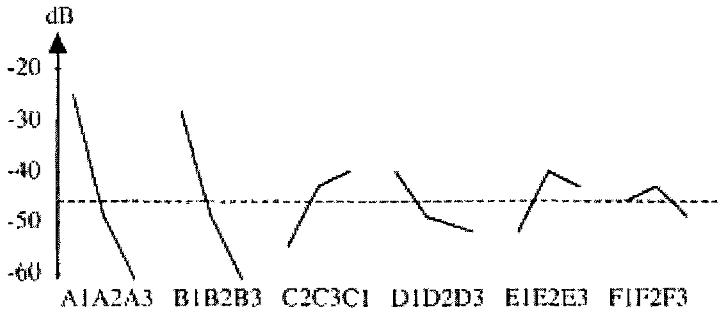
o. *A really bright student will note that allowance will need to be made on diameters C and D for anodizing thickness of around 14 microns!*

b)


Model answer
Why 2 decimal places?
30.20
29.80
5.1
4.9
8.50
7.50
Redundant dimension
A
Ambiguous about which face. Not the conventional symbol (filled in triangle)
0.005
B
Needs a ∅ symbol in front of value. Should not point directly to axis - but to leader line
∅61.15-61.05
∅54.0-53.0
∅D: Loose clearance fit – 41.5 Nominal
Section X-X not labelled
B
Datum B should be on the leader line not the surface - again, not conventional symbol
10.5
9.5
Why 3 decimal places?
19.200
18.800
0.05
A
Not pointing to a specific surface
Missing hole depth, no comment on angle (equispaced)
16 holes M5.0 on a ∅72.5 PCD
Insufficient information for positioning holes - need to dimension them all - or add TYP to these
112.5
111.5
6.05
5.95
X
Missing dimension(s) to position centre of component
No centre lines
8 holes for M6 bolts
Need hole size (e.g. ∅6.3-6.1) & note to say 'thro' material
Notes:
- remove all sharp corners with 45 degree x 0.5 chamfer
Scale: 1:1
Issue.: A
Date:
Checked:
Draw by: A Engineer
Part No.: Exam 1
Material: Al Alloy 6082 TF
Finish: Clear Anodise

Defect level (dB) - overall average reading -45.36

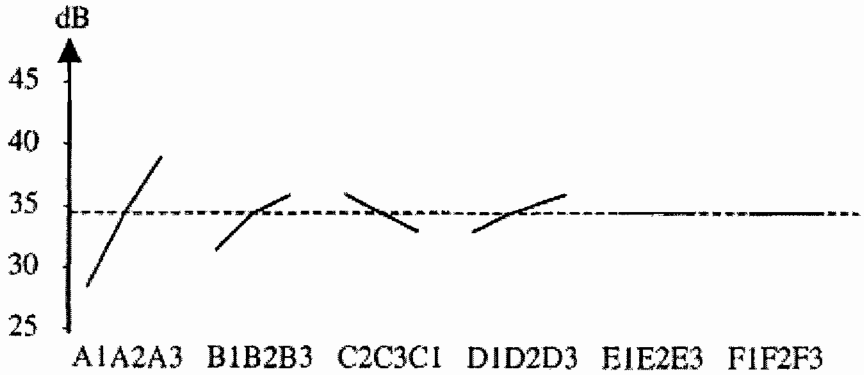
Factor	**Levels**		
	1	**2**	**3**
A. Deposition temperature (^{0}C)	-24.23	-50.11	-61.76
B. Deposition Pressure (mtorr)	-27.55	-47.44	-61.10
C. Nitrogen flow (sccm)	-39.03	-55.99	-41.07
D. Silane flow (sccm)	-39.20	-46.85	-50.04
E. Settling time (min)	-51.53	-40.54	-44.03
F. Cleaning method	-45.56	-41.58	-48.95



(note the order of results for C)

Deposition rate (dB) - overall average reading 34.12

Factor	**Rates**		
	1	**2**	**3**
G. Deposition temperature (^{0}C)	28.76	34.13	39.46
H. Deposition Pressure (mtorr)	32.03	34.78	35.54
I. Nitrogen flow (sccm)	32.80	35.29	34.25
J. Silane flow (sccm)	32.21	34.53	35.61
K. Settling time (min)	34.06	33.90	34.30
L. Cleaning method	33.81	34.10	34.44



(note the order of results for C)

d) The effect of the settling time and cleaning method (E and F) appear to have no efffect on deposition rate, but with both of them at their second settings (eight minutes more settling time and cleaning method 2) the surface defect level reduces. We do not know if the cleaning method adds to the process time but the increased settling time certainly does. These proposed changes need to be considered more fully.

The effects of nitrogen flow and silane flow seem to mirror each other in that more nitrogen seems to decrease the surface defect level and reduce the deposition rate, whereas more silane seems to increase the defect level and also increase the deposit rate. It seems that higher nitrogen and lower silane might be valuable to reduce the surface defect level, whilst reducing the deposit rate.

Increasing the temperature and pressure both increase the deposition rate but at a significant cost in extra surface defects. We do not have enough information to make a clear recommendation here but we can look at the rates. The dB numbers are logs of the squares so for the temperature, the difference in deposition rate between the first and third setting is a factor of 3.4 on the deposition rate, but a factor of 75.3 on the defect level. The equivalent comparison for the pressure is a factor of 1.47 on the deposition rate and a factor of 47.7 on the defect level. It looks as if it might be worth decreasing the pressure, but keeping the temperature moderately high.

Overall, it looks as if it is worth adjusting all the other settings to reduce surface defect level and then using temperature, which is by far the most powerful control on both results, as a single control to set the deposition rate commensurate with an acceptable surface defect level.

c)

Straight forward reading from the data tables in the mechanical design data handbook.

For nominal diameter ∅41.5, a loose clearance fit, the ideal would be H8 – students may also choose H7 which would be OK, but not as idea.

Thus, the tolerance would be … +25um, +0um

= 41.525 – 41.500

For nominal diameter ∅82.0, a tight transition fit would ideally be K7. Again, it is possible to choose either a H6 or a H7, but a K7 would be preferable.

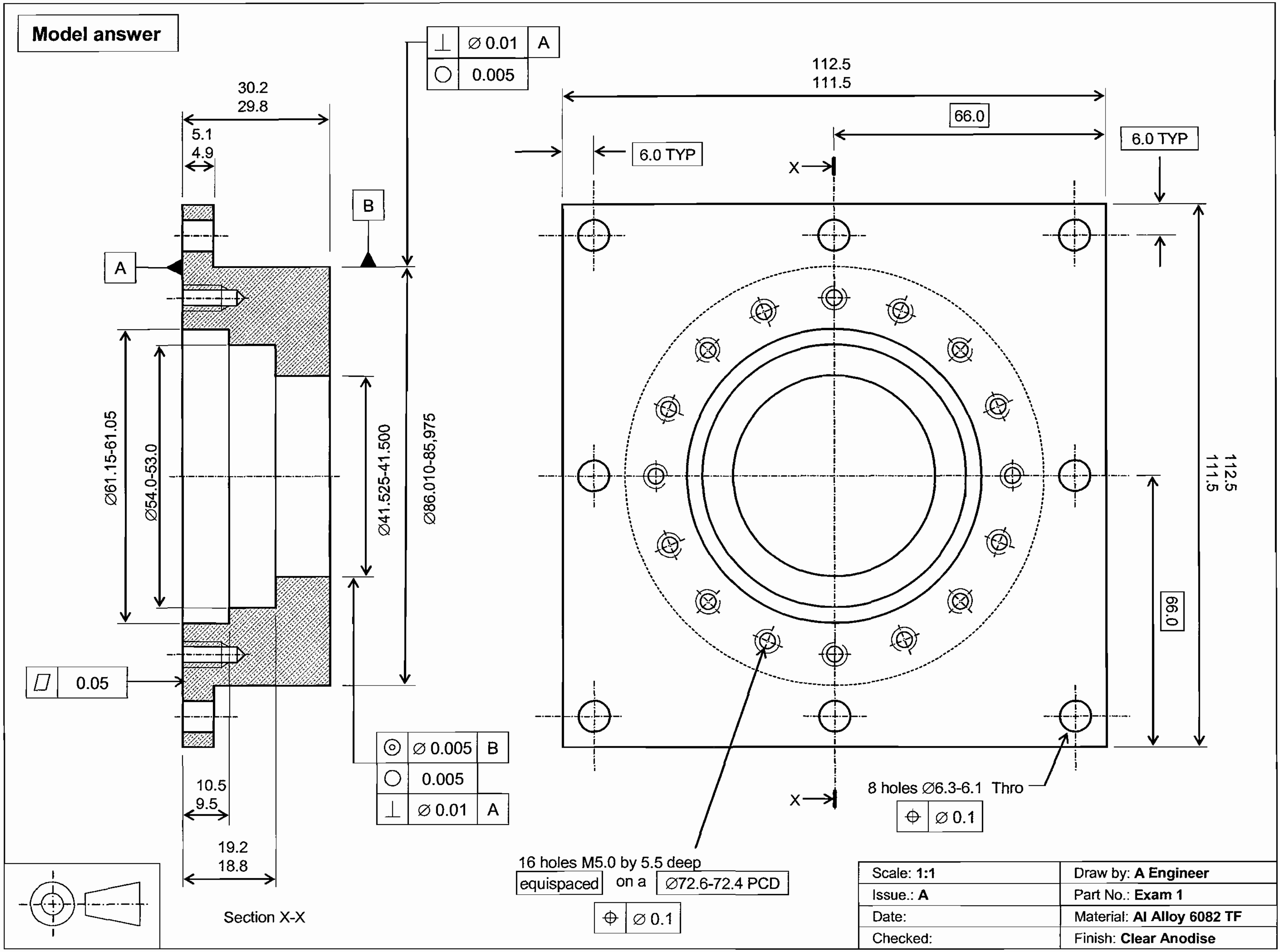
Thus, the tolerance would be +10um, -25um

= 86.010 – 86.975

d)

Answers for d) and e) illustrated over the page

e)


Model answer
⊥ Ø 0.01 A
○ 0.005
30.2
29.8
5.1
4.9
B
A
112.5
111.5
66.0
6.0 TYP
6.0 TYP
X
X
Ø61.15-61.05
Ø54.0-53.0
Ø41.525-41.500
Ø86.010-85,975
0.05
◎ Ø 0.005 B
○ 0.005
⊥ Ø 0.01 A
10.5
9.5
19.2
18.8
Section X-X
16 holes M5.0 by 5.5 deep
equispaced on a Ø72.6-72.4 PCD
⌖ Ø 0.1
8 holes Ø6.3-6.1 Thro
⌖ Ø 0.1
66.0
112.5
111.5
Scale: 1:1
Issue.: A
Date:
Checked:
Draw by: A Engineer
Part No.: Exam 1
Material: Al Alloy 6082 TF
Finish: Clear Anodise

Question 4: ***answers:***

b)

To be fully in control, plus/minus 3xstandard deviations would cover over 99% (99.73% to be precise) of parts. Thus, 2xSD = 2.1mm. Therefore, a sensible USL would be the mean plus 2.1 and a sensible LSL would be the mean minus 2.1.

Therefore, USL = 255.1 + 2.1 = 257.2 and LSL = 255.1 – 2.1 = 253.0

c)

The formula for Cpk is the minimum of (USL-mean)/3xSD and (mean-LSL)/3xSD

Thus, applying this formula, with a USL of 257.2 and a LSL of 253:

	Morning shift			Afternoon shift		
	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6
Mean values	μ_1=255.1	μ_2=256.3	μ_3=257.0	μ_4=255.0	μ_5=256.1	μ_6=256.8
Standard deviations (SD)	σ_1=0.7	σ_2=0.6	σ_3=0.4	σ_4=0.35	σ_5=0.3	σ_6=0.25

Calculations:

3xSD	*2.1*	*1.8*	*1.2*	*1.05*	*0.9*	*0.75*
USL (257.2) - mean	*1.00*	*0.50*	*0.17*	*2.10*	*1.22*	*0.53*
X = (257.2-mean)/3xSD	*2.1*	*3.3*	*4*	*2*	*3.1*	*3.8*
Mean – LSL (253)	*1.00*	*1.83*	*3.33*	*1.90*	*3.44*	*5.07*
Y = (mean-253)/3xSD	*1.00*	*0.50*	*0.17*	*1.90*	*1.22*	*0.53*
CpK (minimum of X & Y)	***2.1***	***0.9***	***0.2***	***2.2***	***1.1***	***0.4***

d)

The process is only just in control for the first batch – with a value of 1, as it is perfectly centred and evenly spread for this ideal case.

In all subsequent cases, apart from batch 4, the process is incapable of producing components within the limits established in part (a) of the question.

a. *batch 2: the spread is less than for batch 1, but the mean value has increased – SKETCH DISTRIBUTION CURVE*

b. *batch 3: the spread is again smaller, but again the mean value has increased – SKETCH DISTRIBUTION CURVE*

c. *batch 4: after the shift change, the spread is again under control, but the mean size is now the same as at the start of the morning shift – SKETCH DISTRIBUTION CURVE. The CpK value indicates that the process here is more than capable of producing the components.*

d. *batch 5: mean size has grown again, and spread (SD) continues to fall – SKETCH DISTRIBUTION CURVE*

e. *batch 6: the spread is again less than the first batch, but the mean has continued to grow – SKETCH DISTRIBUTION CURVE*

Overall, the process could be described as being precise within a sample, but not accurate over all samples. It appears as if once set up for the morning's production, the process remains precise, but gradually deviates away from the mean size – an offset error. Following the afternoon shift change, the process remains precise, but the size again grows during the shift. NOTE: SKETCH OF ACCURACY & PRECISION. Throughout the day, the process becomes gradually more precise, with the standard deviation falling rapidly in the first batch and levelling off.

To improve the process, attention needs firstly to be given to why the average size is increasing throughout the morning and afternoon shifts. This could be due to a number of reasons: changes in temperature, poor machine design etc. To reduce the spread could be harder, as this appears to be a fairly consistent property of the production process. However, as the SD reduces throughout the day, it does suggest that the machine settles following early production. It may be possible to achieve lower SD levels all day if the machine is started running earlier

e)

LSL: Taking the worst case scenarios, smallest mean with largest standard deviation, would be 255.0 – (3 x 0.7) = 252.9

USL: again, worst case scenario, largest mean with largest standard deviation, would be 257.0 + (3x 0.7) = 259.1

Thus, the spaghetti could be made reliable with a tolerance limit of 259.1-252.9

f)

On the surface, their request seems unrealistic, given the ranges calculated in part d. However, if the gradually increase in size can be overcome through regular inspection and machine resetting, then it may not be so unrealistic.

254.5-253.5 is equivalent to 254.0±0.6. Thus, 3 x standard deviations would be 0.6. Thus, the desired SD is 0.6/3 = 0.2. This would need a fivefold improvement on current production and to achieve this would be hard. However, the best that is currently being achieved is 0.25, with a more realistic value being 0.4.

I would thus negotiate with the design office that a realistic target would be 254.0±1.2 (or 23.8 – 25.2) which would demand improvements in both offset and spread that should be achievable.

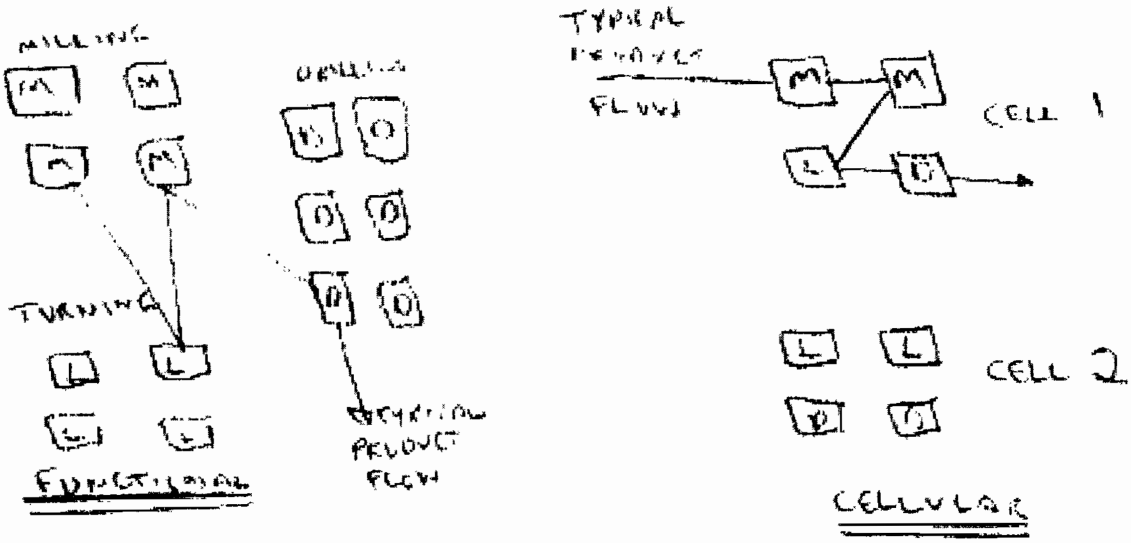
f)

The process capability calculations are based around plus/minus three standard deviations. Thus, 99.73% of parts are within spec. However, for very high production volumes, there may still be a significant number of parts that are out of spec. The six sigma viewpoint – started by ...

Qu 5.

a) A functional layout groups machines and processes together by type. For example, all the lathes would be together in one department, all the milling machines would be together in another.

A cellular layout groups together all the processes to manufacture a particular product or group of products See diag.



Advantages of Cellular layout

Shorter Throughput times less queueing and transport between processes

Reduced inventory – due to above, less safety stock required and less buffering

Simplified planning and control – at factory level, cells make complete, routes less complex.

Reduction of set-up times due to commonality of product, familiarity, specialised tooling, learning curve effects.

Improved quality, Improved productivity can also be achieved for similar reasons

Cellular layout when combined with group technology can lead to improved designs, design for manufacture

Problems

Skills With a functional layout, operators become highly single skilled, with cellular there is need for some multi-skilling to balance workloads

Plant generally plant utilisation will be lower, and there is greater disruption if items of plant break down, and there is only one item in the cell.

Control – at the cell level can become more complex, local autonomy in loading and scheduling

Product change – may cause problems if cells require reconfiguring.

b) Activity relationship diagram assuming transport is the key factor.

To

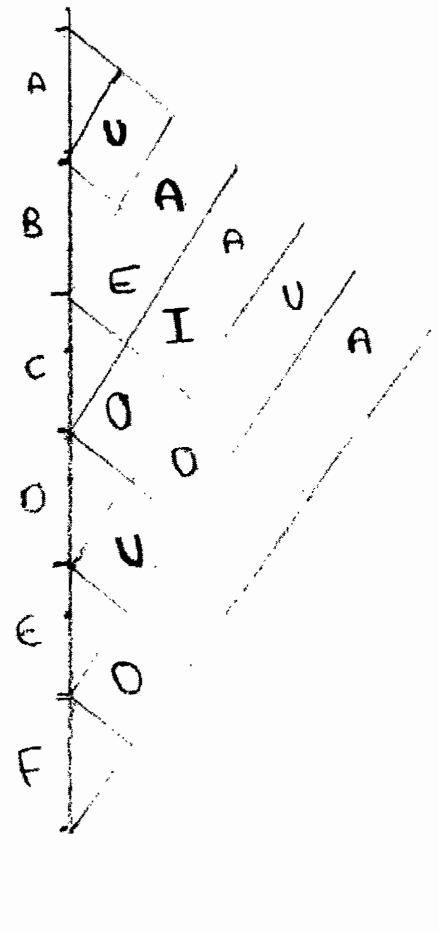
		A	B	C	D	E	F
	A		2000		6000	500	3500+ 6000
	B			2000+3500+ 2500	500		
From	C	3500+500+ 6000	500		2000+ 2500		
	D	6000	3500+ 2500			2000+ 500	
	E			2500+500			2000
	F	6000				2500	

	A	B	C	D	E	F
A		2000	10000	12000	500	15500
B			8500	6500		
C				4500	3000	
D					2500	
E						4500
F						

We can assign

$\geq$10000 = A; 7500-10000 = E; 5000-7500 = I; 2500 5000 O; $\leq$2500 = U

An alternative representation is .



ii) The best way to answer this part of the question is to use the technique of Systematic Layout Planning. Diagram shows stages.

The data we have so far is on flow of materials, other data that we might need to input to activity relationship chart might include requirements for supervision, communication support and any environmental constraints.

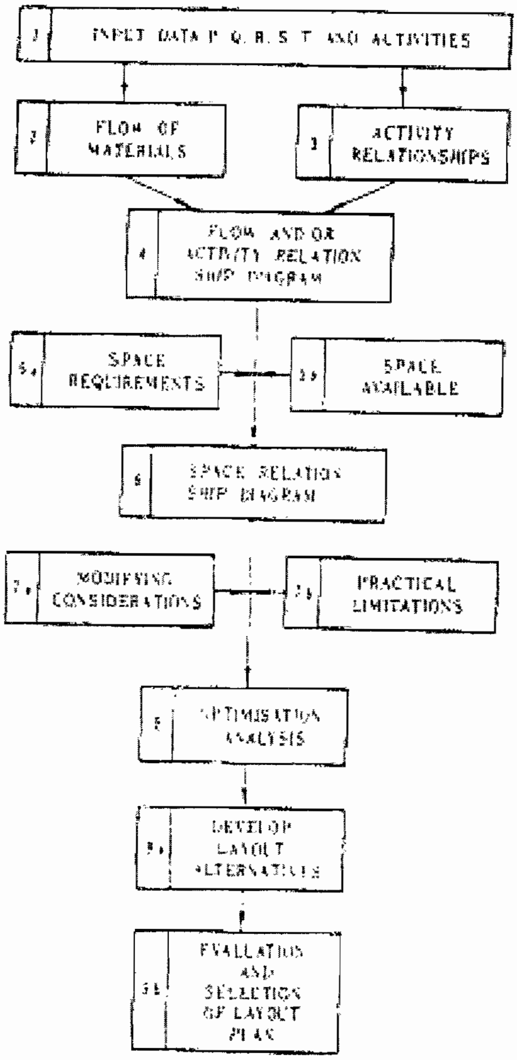
Next stage is to consider space requirements. Need data on area occupied by each department. In additional to area for process equipment, need to include gangways, storage etc.

From this space relationship diagram created, bringing together activity relationship diag and space requirements. This shows, graphically, departments drawn to scale and positioned iteratively to achieve best satisfaction of AEIOUX requirements.

'Ideal' layout is now modified to fit actual shape of factory. Need to know position of pillars, walls, routing of drains, services etc.

Final stage is fine tuning.

Several alternative layouts might be developed, and evaluated using structured techniques such as factor analysis or AHP.



Qu. 6

a) Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

BS 3138:1969

The basic procedure for method study is as follows:

SELECT	the work to be studied.
RECORD	all the relevant facts about the present method by direct observation
EXAMINE	those facts critically and in ordered sequence
DEVELOP	the most practical, economic and effective method
DEFINE	the new method so that it can always be identified.
INSTALL	that method as standard practice.
MAINTAIN	that standard practice by regular checks

(candidates may expand the above.)

b)

Activity sampling is used for finding the percentage occurrence of a certain activity by statistical sampling and random observations.

The basic principle is that if a number of random observations (N) are made of an event and n of these observations are of an outcome i, then the expected proportion of times that the outcome i will occur is n/N.

b)

$$n = \frac{Z_c^2}{k^2}\left(\frac{1-p}{p}\right) \qquad Z_c = 1{\cdot}64 \text{ (for 90\% confidence)}$$

k is fractional error $\qquad kp = 0{\cdot}05 \qquad k = \frac{0{\cdot}05}{p}$

Estimate of p	$\left(\frac{1-p}{p}\right)$	k	n
0·80	0·25	0·062	172
0·70	0·43	0·07	226
0·5	1	0·1	269

The table above shows the calculations for the sample size to be 90% confident that each machine attribute is within ±5% of table. The 50% attribute [illegible] requires the largest sample of [illegible] 269 (≈270 if rounded), so the [illegible] should have [illegible] observations.

Steps in carrying out the Activity Sampling study

The required accuracy and required confidence limits specified in the question define the number of observations required. To ensure that the max. error is less that that specified we have to plan to take the highest number of observations (270) (This means that the accuracy, for the more machines utilised 70% and 80% will be better than specified.)

Design of the main study.

270 observations made over a 10 day period, would require making about 4 observations/hour on average.

The easiest way to do this would be to get the foreman to record the machine states (eg working, idle, broken down etc.) at specified periods throughout the day. The periods must be determined randomly (important).

At the end of each shift, data is summarised and plotted, using both control charts and cumulative plots to ensure the study is 'in control' and to spot any unusual variations in utilisation.

At the end of the study, the values from the observations are substituted back into the formula and the final accuracy of the study is calculated and checked to be within the limits.

c) Advantages and Disadvantages of Activity Sampling vs. Time Study

Advantages

1 Many operations or activities which are impractical or costly to time study can readily be measured by activity sampling.

2. A simultaneous activity sampling study of several operators or machines may be made by a single observer. A work study engineer is needed for each operator or machine when continuous time studies are made.

3. It usually requires fewer man-hours and costs less to make an activity sampling study than it does to make a continuous time study.

4. Observations may be taken over a period of days or weeks, thus decreasing chance of day-to-day or week-to-week variations affecting the results.

5. It is not necessary to use trained work study engineers as observers for activity sampling studies unless performance sampling is required

6. An activity sampling study may be interrupted at any time without affecting results

7. Activity sampling measurements may be made with a preassigned degree of reliability.

8. With activity sampling the engineer makes an instantaneous observation of the operator at random intervals during the working day, thus making prolonged time studies unnecessary

9. Activity sampling studies are less fatiguing and less tedious for the observer.

10. Activity sampling studies are often preferred to continuous time studies by the operators being studied. Some people do not like to be observed continuously for long periods of time

11. A stop watch is not needed for activity sampling studies.

Disadvantages

1. Ordinarily activity sampling is not economical for studying a single operator or machine, or for studying operators or machines located over wide areas. (The observer spends too much time walking to and from the work place or walking from one work place to another.)

2. Time study permits a finer breakdown of activities and delays than is possible with activity sampling. Activity sampling cannot provide as much detailed information as one can get from time study.

3. The operator may change his or her work pattern upon sight of the observer. if this occurs, the results of such an activity sampling study may be of little value.

4. An activity sampling study made of a group obviously presents average results,. there is no information about individual differences.

5. Management and workers may not understand statistical activity sampling as readily as they do time study.

6. In certain kinds of activity sampling studies, no record is made of the method used by the operator. Therefore, an entirely new study must be made when a method change occurs in any element.

7. There is a tendency on the part of some observers to minimize the importance following the fundamental principles of activity sampling, such as the proper sample size for a given degree of accuracy, randomness in making the observation, instantaneous observation at the preassigned location, and careful definition the elements or subdivisions of activity or delay before the study is started.

Question 7 Answers.

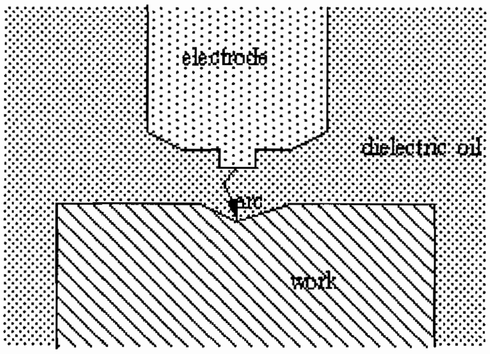
a) **Tool Steels.** Tool steel moulds offer the most precision on longest tool life. This material is general chosen when high temperature materials are to be moulded or when high volume production runs are required. Typical production volumes for a Tool steel mould can run into millions or shots, even for difficult materials like glass filled nylons. They are difficult to make and carry a cost penalty compared to inferior tool materials.

Al Alloys. Al alloys are often chosen when simple cavities are required or when the production runs are of the order of ~ several hundred thousand shots. The low melting point and toughness of Al alloys tend to limit tool life to less than ~500k shots depending on the injection materials. They can be machined very easily and or considered to be a medium cost tooling option.

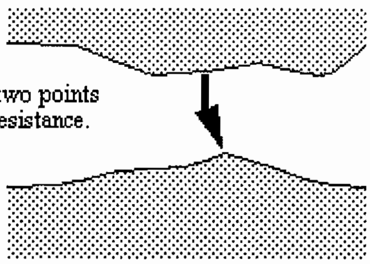
Expoxy Resins. Expoxy resins are often called "soft-tooling", these tools are often chosen as prototype tooling options when the design is still live or when very short production runs are required. The lifetime of the tools is often very limited ~ 2000 shots depending on the injection material.

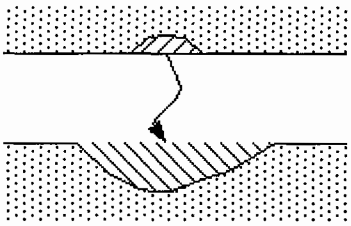
b)

i) Basic EDM process.

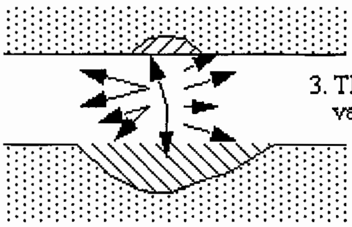


1. An arc jumps between two points along the path of least resistance.

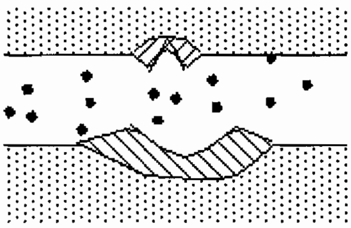




2. The energy of the arc is so concentrated that it causes the electrode, and the work to melt. But the electrode material is chosen so that it melts less.



3. The metal and dielectric fluid are partly vaporized, causing sudden expansion.



4. The blast from the expanding vapors knocks some molten particles loose, and the remaining molten metal hardens.

1. 1. charge up an electrode
2. 2. bring the electrode near a metal workpiece (oppositely charged).
3. 3. as the two conductors get close enough a spark will arc across a dielectric fluid. This spark will "burn" a small hole in the electrode and workpiece.
4. 4. continue steps 1-3 until a hole the shape of the electrode is formed.

Typical electrode materials are,

1. - copper,
2. - tungsten
3. - graphite

The user can select the following parameters

1. - Electrode material
2. - Electrode polarity +/-
3. - pulse current If (A)
4. - pulse duration ti (micro s)
5. - pulse off time to (micro s)

6. - average voltage U (V)
7. - Average current I (A)
8. - working current density
9. - open gap voltage Vo (V)
10. - Dielectric - flushing mode

The process is based on melting temperature, not hardness, so any conductive material can be machined in this way including heat treated tool steels.

Fluid

1. - fluid is used to act as a dielectric, and to help carry away debris. It is quite often kerosene based oil.
2. - if the fluid is pumped through and out the end of the electrode, particles will push out, and mainly collect at the edges. They will lower the dielectric resistance, resulting in more arcs. As a result the holes will be conical.
3. - if fluid is vacuum pumped into the electrode tip, straight holes will result.

Better answers may include some of the following information.
The arc that jumps heats the metal, and about 1 to 10% of the molten metal goes into the fluid. The melted then recast layer is about 1 to 30 micro m thick, and is generally hard and rough. The electrode workpiece gap is in the range of <10 micro m to <100 micro m. The process uses a voltage discharge of 60 to 300 V to give a transient arc lasting from 0.1 micro s to 8 ms. Typical cycle time is 20 ms or less, up to millions of cycles may be required for completion of the part. Electrode materials are high temperature, but easy to machine, thus allowing easy manufacture of complex shapes.

Typical machine parameters are,

PARAMETER	TYPICAL VALUE
power (KW)	0.5-1.5
in.**3/hr.	.18-1.1
electrode wear (%)	1-10
surface (micro in. RMS)	12

b ii) When the energy density is increased this leads to

1. – higher machining rates
2. – increased recast layer thickness
3. – increased tool wear rate
4. – increased surface roughness

5. – reduced precision through rounded edges and taper.

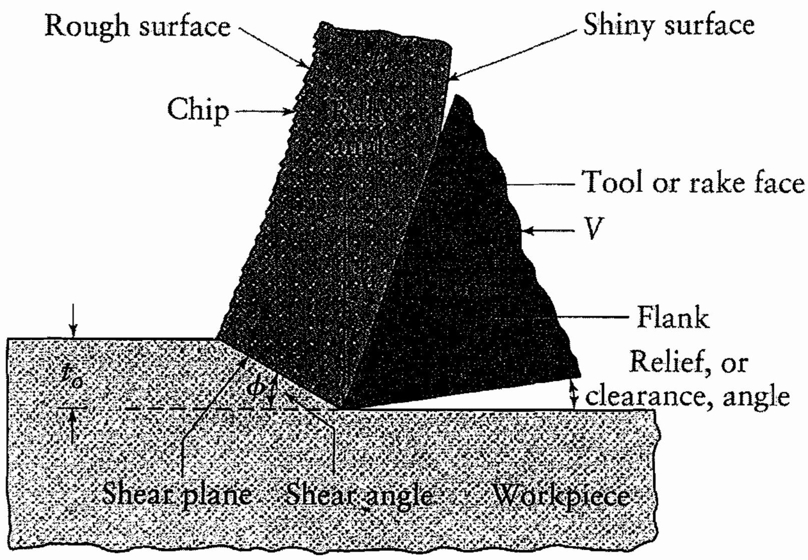
c) Non-mechanical processes that can compete directly with EDM for the production of precision tooling could be draw from the following list.
Electro-chemical machining
Direct laser machining
Direct metal laser sintering
Water-jet cutting for 2.5D components (extrusion dies)

Q8: Answers

a) Any four of the following for each category
i) Turning, boring, drilling, tapping, milling, sawing, broaching
ii) Grinding, honing, lapping, ultrasonic machining
iii) Electromagnetic discharge machining, electrochemical machining, chemical machining, plasma etching, laser machining, plasma cutting, oxy-fuel cutting

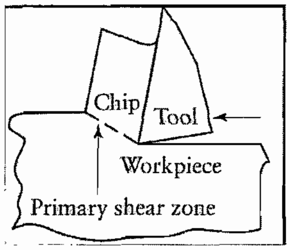
b)

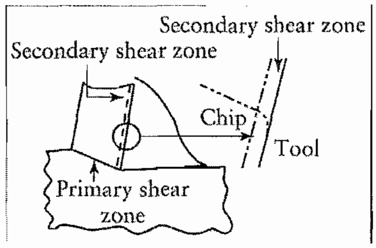
The basic mechanics of chip formation is the same for all cutting operations and can be represented by the two dimensional model shown in the figure. In this case, the tool moves along the workpiece at a certain velocity, V, and a depth of cut, t_0. A chip of thickness, t_c, is produced just ahead of the tool by shearing of the material continuously along the shear plane. The shear plane can be defined by the shear angle, ϕ. Below the shear plane the material is undeformed, although it does undergo some elastic distortion. Above the shear plane, the chip is formed and moves up the face of the tool as cutting proceeds. The rake angle, α, can be positive or negative and is determined by the geometry of the tool. Because of the movement of the chip, there is friction between the chip and the rake face of the tool. The negative effects of this friction, i.e thermal load and tool wear, can be reduced by supplying cutting lubricants.



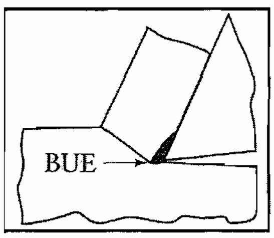
c)

Continuous chips are usually formed at high cutting speeds and or high rake angles; the deformation of the material takes place along a very narrow shear zone, called primary shear zone. Continuous chips may also develop a secondary shear zone at the tool chip interface caused by friction, the greater the friction the greater the depth of the secondary shear zone.

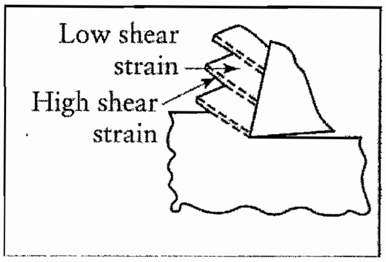




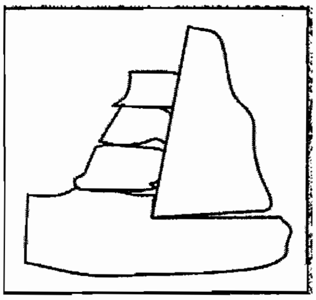
Built up edge chips (BUE) may form at the tip of the tool during cutting; it consists of layers of material from the workpiece that are gradually deposited on the tool. As it increases in size, the BUE becomes unstable and breaks up. Some of the BUE is carried away by the chip and the rest is often deposited randomly on the workpiece surface. BUE formation can significantly affect the machining process as the geometry of the cutting process is changed.



Serrated chips or **Segmented chips** are semi-continuous chips, with zones of low or high shear strain. The chips have the appearance of saw teeth. Metals with low thermal conductivity or metals with strong yield-stress temperature dependence exhibit this behaviour.



Discontinuous chips consists of segments that may be either firmly or loosely attached to each other. These chips usually form when: the workpiece is made of a brittle material; the workpiece contains inclusions; the workpiece contains structures, such as graphite in cast iron; cutting fluid supply is too low, machining rates are too high or too low.



d)

i) *The rotational rate for the spindle is*

$\omega = v_s / \pi D = 12{,}500/(3.142 \times 50) = 79.6$ rev/s

Now, calculating the workpiece velocity, v,

If the workpiece moves at a rate 'v', the travel in time 't' is 'v .t'. In this time the cutter would rotate 'ω. t' times and the workpiece would see 'N.ω.t' teeth. The feed per tooth is then $f = v / (N\,\omega)$.

v is then given by **v** $= f.N.\omega = 55.70$ mm/s

Power requirement for machining is given as $P = u_s$. MMR

Material Removal Rate MMR *is given by*
$v \cdot w \cdot d = 55.72 \times 25 \times 2.5 =$ **3482.25 mm³/s**

ii)

Therefore the power requirement for cutting is
P = 1.1 x 3482.25 = **3830.50 W**

END OF CRIB