NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2017-2018

MA2004 – MANUFACTURING PROCESSES

November/December 2017 Time Allowed: $2^1/_2$ hours

Seat No:

Matriculation No:

INSTRUCTIONS

1. This paper contains **SIX (6)** questions and comprises **ELEVEN (11)** pages.
2. Answer **All** questions.
3. Marks for each question are as indicated.
4. All your answers should be contained in this answer booklet and within the space provided after the question.
5. Do not attach any other paper or string.
6. This is a **RESTRICTED OPEN-BOOK** examination (1 sheet of double-sided A4 reference paper is allowed).
7. **Do not** write in the right hand column.

Question No	Mark
1	
2	
3	
4	
5	
6	
Total	

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1. Please provide short answers to the following questions:

(a) Define surface roughness. Give an example of how surface roughness is measured.

(4 marks)

(b) What is the difference between a core and a pattern in sand moulding?

(4 marks)

(c) What is spring-back in sheet-metal bending? What can you do to avoid spring-back?

(4 marks)

Note: Question 1 continues on page 3.

(d) Casting 1 is a cube of H centimeter on each side. Casing 2 is a sphere of diameter H centimeter. Both castings have the same mould constant and exponent (where n = 2). Find the ratio of {total solidification time of casting 1} over {total solidification time of casting 2}.
[Hint: Volume of sphere $V = \frac{4}{3}\pi r^3$; surface area of sphere $A = 4\pi r^2$, r is radius.]
(4 marks)

(e) A blanking die is to be designed to blank the part outline shown in Figure 1. The material is a 3-mm-thick stainless steel having an allowance a = 0.075. Determine the dimensions of the blanking punch and the die opening. You should draw the die and the punch opening, and label the lengths of edges clearly.
(4 marks)

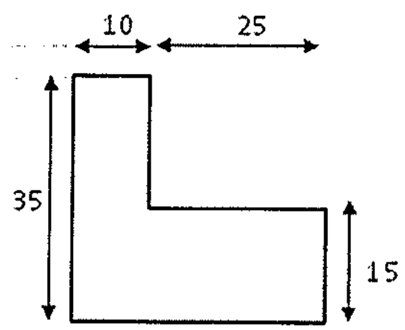

Figure 1 (All dimensions shown in mm.)

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2. The following questions concern Deep Drawing of a Cylindrical Cup:

(a) Starting with a blank size of 150 mm and the stock thickness of 2 mm, if the cup inner diameter is 80 mm and cup height is 45 mm, is the operation feasible?

(5 marks)

(b) Continuing from part (a), you decided to save some material cost. You try to use a starting blank size that is smaller. What is the smallest starting blank diameter you need to make this operation still feasible?

(4 marks)

Note: Question 2 continues on page 5.

(c) After the drawing operation, the foreman shows you several samples of the parts that have been deep drawn in the shop. Some have ears, and some have wrinkles. What remedies would you propose to avoid ears and wrinkles?

(6 marks)

/ 15

3. The following questions concern process in manufacturing a product:

A well-known chocolate manufacturer has one very popular product. It is an egg-shaped chocolate, and there is a small toy embedded inside the chocolate egg as a "surprise" fun for kids. The toys have very sophisticated and detailed features, and are also rich in colours. The surface finishing is excellent.

The company has an entire team of people focusing on design and manufacturing of the surprises. One day they came to you and ask you to help manufacturing their surprises.

The surprises are made by plastics. A mould is used for the manufacturing, and it can be used to produce 5 million counts of the same surprise. It's a huge amount of production. They require you to produce 32 surprises per minute due to the large volume and short turn-around time required.

(a) Which process will you use to make the surprises? Circle your answer below.

(3 marks)

Injection moulding / Sand casting / CNC machining / 3D printing

Note: Question 3 continues on page 6.

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(b) The mould needs to be used for 5 million times. Which process will you use to make the mould? Circle your answer below.

(3 marks)

Injection moulding / Sand casting / CNC machining / 3D printing

(c) You are to inspect a hole dimension in the mould for the surprise. The hole has a diameter of 10.00 ± 0.20 mm. A wear allowance of 2% of the total tolerance band is to be included in the design of your gage. Determine the nominal sizes of the GO gage and the NO-GO gage.

(4 marks)

(d) You found that the dimensions of the surprises you manufactured were all smaller than what your client asked for. You double checked, and the moulds were all designed to be the same dimensions as the design of the surprises by the client. What would be the reason for such a mistake?

(5 marks)

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4. This question relates to welding and joining processes.

(a) What is the name of the welding process shown in Figure 2? Do you need to use shielding gas in the welding process? Is this a fusion welding process or solid-state welding process? Give your reasons.

(5 marks)

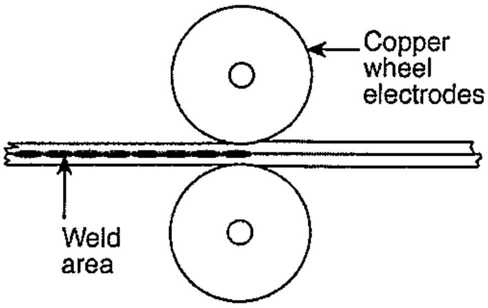

Figure 2

(b) It is required to join an aluminium alloy with a stainless steel to produce the next generation of hard disks. Would you recommend using arc welding for the purpose? If not, which manufacturing process would you recommend? Give your reasons.

(5 marks)

Note: Question 4 continues on page 8.

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(c) What is welding volume rate (WVR)? Calculate WVR in an arc welding process if the following can be assumed: welding voltage E = 24 V, welding current I = 150 A, heat transfer efficiency $f_1 = 0.75$, melting efficiency $f_2 = 0.8$, welding speed v = 120 mm/min, and unit melting energy of the workpiece material $U_m = 10.1\ J/mm^3$.
(5 marks)

/ 20

5. This question relates to machining processes.

(a) What are the names of the machining processes shown in Figure 3(a) and Figure 3(b)? Which of the two machining processes is more commonly used? Why?
(5 marks)

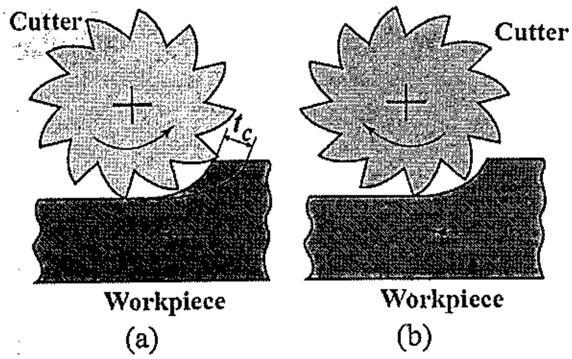

Figure 3

Note: Question 5 continues on page 9.

(b) Why is tungsten carbide selected as a material for making cutting tools? Do you expect tungsten carbide cutting tools to produce a better surface finish on parts and allows faster machining than cutting tools made of high speed steels? Give your reasons.

(5 marks)

(c) How would you expect the cutting force and specific energy for machining to be affected when the shear angle is reduced or the friction angle is increased? Give your reasons.

(5 marks)

Note: Question 5 continues on page 10.

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(d) An alloy workpiece of 88 mm in diameter is turned on a lathe to diameter 80 mm in a single pass. The length of cut is 600 mm, the spindle rotates at 580 rev/min, and the tool travels at a linear speed of 300 mm/min along the workpiece length. Calculate the material removal rate and machining time.

(5 marks)

/ 15

6. This question relates to microelectronics manufacturing.

(a) What is doping in a microelectronics manufacturing process? What is the purpose of doping? Is it a type of "layer processing"? Describe two techniques for doping silicon.

(5 marks)

Note: Question 6 continues on page 11.

(b) What is the role played by photoresist in a microelectronics manufacturing process? What is the difference between a positive photoresist and a negative photoresist? Would you prefer to use ultraviolet light or infrared light in a photolithographic process? Give your reasons.

(5 marks)

(c) Show the step-by-step procedures for fabricating a gold wire in a silicon wafer.

(5 marks)

END OF PAPER

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① a) Surface roughness is a measure of deviations from the nominal surface. It is usually represented as arithmetic average (average of deviations over a number of points on surface) and also vertical distance from highest deviation to the lowest. Measurement of the deviation of a point can be obtained by stylus test or fingernail test (subjective comparison)

b) Core → placed inside mold cavity to define interior geometry of part
Pattern → define external geometry of part, usually made by machining and used to create the mold cavity.

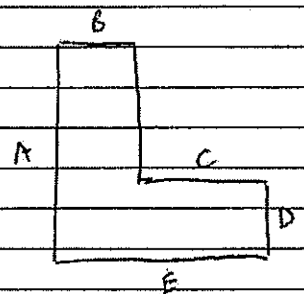
c) Spring back is the increase in included angle after bending due to metal's elastic recovery. Can be solved by doing overbending so that the metal will spring back to the desired angle. Can also be solved by introducing compressive pressure at the bend area to create plastic deformation (bottoming).

d) $V_1 = H^3$; $A_1 = 6H^2$

$V_2 = \frac{4}{3}\pi\left(\frac{H}{2}\right)^3 = \frac{1}{6}\pi H^2$; $A_2 = 4\pi\left(\frac{H}{2}\right)^2 = \pi H^2$

$$\frac{T_1}{T_2} = \frac{C_m\left(\frac{V_1}{A_1}\right)^n}{C_m\left(\frac{V_2}{A_2}\right)^n} = \frac{\left(\frac{H^3}{6H^2}\right)^2}{\left(\frac{\frac{1}{6}\pi H^3}{\pi H^2}\right)^2} = 1$$

e) $c = at = 0.075 \times 3 = 0.225$ mm



For punch

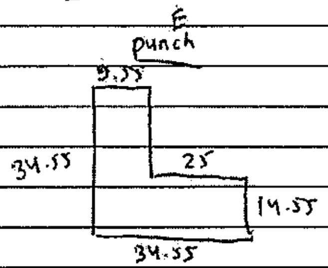
$A = 35 - 2 \times 0.225 = 34.55$ mm

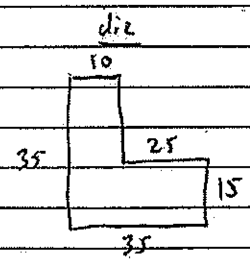
$B = 10 - 2 \times 0.225 = 9.55$ mm

$D = 15 - 2 \times 0.225 = 14.55$ mm

$E = 35 - 2 \times 0.225 = 34.55$ mm

$C = 25$ mm





All dimensions are in mm

(2) a) → $DR = \frac{D_b}{D_p} = \frac{150}{80} = 1.875 < 2$ → feasible

→ $r = \frac{D_b - D_p}{D_b} = \frac{150-80}{150} = 0.47 < 0.5$ → feasible

→ $\frac{t}{D_b} = \frac{2}{150} = 0.013 > 0.01$ → feasible

→ $D_b \geq \sqrt{D_p^2 + 4D_p h}$

$150 \geq \sqrt{80^2 + 4 \times 80 \times 45}$

$150 \geq 144.22$ → feasible

∴ Operation is feasible

b) $D_b \geq 144.22$ mm (see point (a))

c) Avoid ears → reduce anisotropy of metal by heat treating or use isotropic metal to begin with

Avoid wrinkles → increase blankholder force

(3) a) Injection molding → good surface finish, allow automatic production, fast production

b) CNC machining → good surface finish, metal is more durable (better than sand casting)

c) Wear allowance = 2% × (0.2 − (−0.2)) = 0.008 mm

GO size = 10 − 0.2 + 0.008 = 9.808 mm

NO-GO size = 10 + 0.2 = 10.2 mm

d) - Low injection pressure → causes less material to enter mold cavity

- Low temperature → causes higher polymer viscosity → less material entering mold cavity

(4) a) Resistance spot welding - No need shielding gas because the process doesn't employ arc and is relatively fast. Can be fusion welding (if base metal melts) or solid-state welding (if base metal doesn't melt)

b) No. We can use laser welding to create more precise weld and smaller weld area because hard disks' parts are small & delicate.

c) $WVR = \frac{f_1 f_2 VI}{U_m} = \frac{0.75 \times 0.8 \times 24 \times 150}{10.1} = 213.86\ mm^3/s$

(5) a) 3a is conventional / up milling. 3b is climb / down milling.
Up milling is more commonly used because it starts cutting from small thickness to gradually larger and it doesn't consider hard surface. Down milling will have larger wear & damage due to cutting from the hard surface.

b) Because tungsten carbide has high hot hardness (high hardness in elevated temperature), high toughness, and high wear resistance. Using tungsten carbide would allow faster machining because we need lower speed when using high speed steel to prevent overly high temperature due to its lower hot hardness.

c) Cutting force will increase to overcome larger friction. Specific energy will also increase because more energy is dissipated as heat, thus we will need more energy to do the process.

d) $fN = 300\ mm/min$

$D_{avg} = \frac{1}{2}(80 + 88) = 84\ mm$

$d = \frac{1}{2}(88 - 80) = 4\ mm$

$MRR = dfV = df\pi D_{avg} N$

$= 4 \times \pi \times 84 \times 300$

$= 316672.5\ mm^3/min$

$= 5277.88\ mm^3/s$

$t = \frac{l}{fN} = \frac{600}{300} = 2\ min$

(6) a) Doping is the process of introducing impurities to the material in order to alter its electrical properties. It's not a type of layer processing because it doesn't need to be done layer by layer and can be directed to just a particular area.

1) Diffusion: impurities diffuse from dopant gas (high concentration) to material (low concentration)

2) Ion implantation: impurity ions accelerated by electric field and directed at the substrate and it will penetrate the substrate and stop.

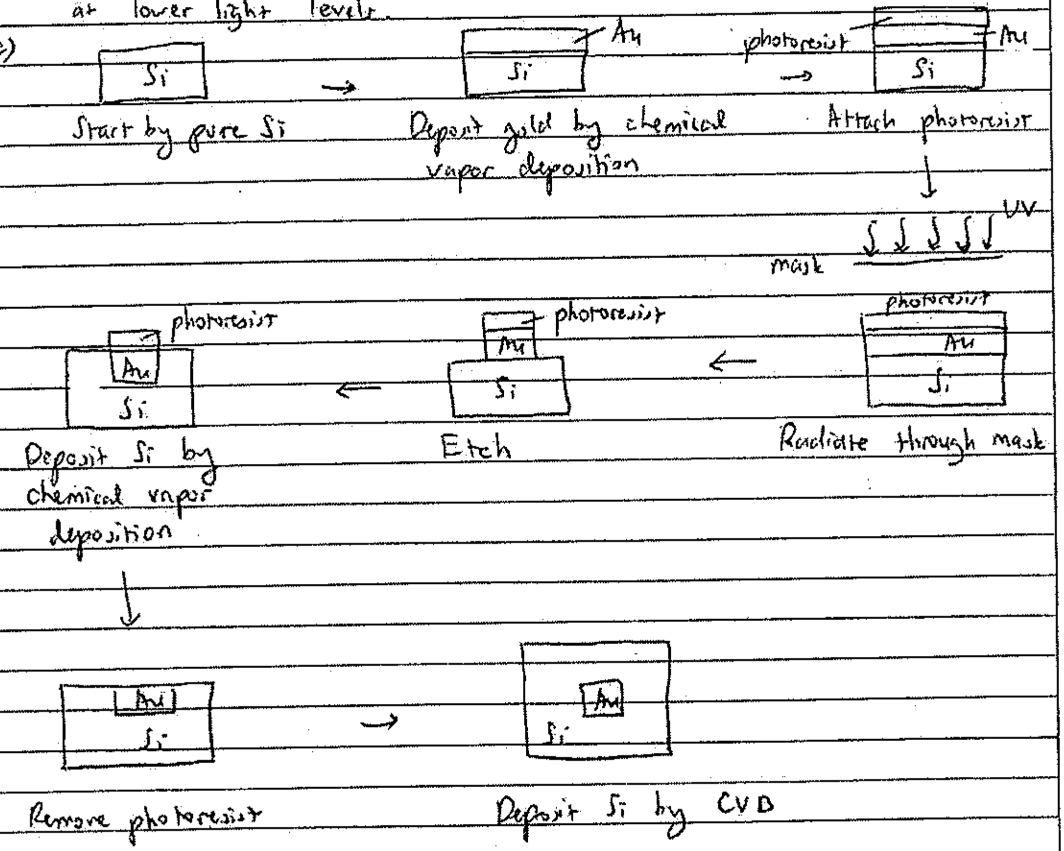
b) Photoresist is used to transfer the pattern to substrate surface. It allows certain part to be etched and prevents the rest being etched.

Positive : Areas exposed to radiation will be more soluble and hence can be dissolved by etching.

Negative : Areas exposed to radiation will increase its resistance to etching. Etching can dissolve area not radiated.

UV light is preferred → shorter wavelength permitting sharper imaging on surface. Fabrication can be done in plant illuminated at lower light levels.

c)



NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2017-2018

MA2004 – MANUFACTURING PROCESSES

April/May 2018 Time Allowed: 2½ hours

Seat No.:

Matriculation No.:

INSTRUCTIONS

1. This paper contains **SIX (6)** questions and comprises **SEVENTEEN (17)** pages including **ONE (1)** page of Appendix.
2. Answer **ALL** questions.
3. Marks for each question are as indicated.
4. All your answers should be contained in this answer booklet and within the space provided after the question.
5. This is a **RESTRICTED-OPEN BOOK** examination (1 sheet of double-sided A4 reference paper is allowed).

Question No	Mark
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Total	

79

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1. Please give short answers to the questions.

(a) Describe what process you will choose to mass produce the metal cover for a cell phone and explain your choice.

(4 marks)

casting of metals will be chosen.

1.) Net shape or near net shape process, ~~so for the~~ Parts with complex feature like the metal cover can be produced without need for additional operation.

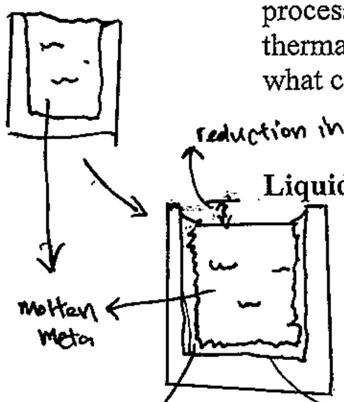
2.) create complex geometry required

3.) can produce external ~~inf~~ internal shape.

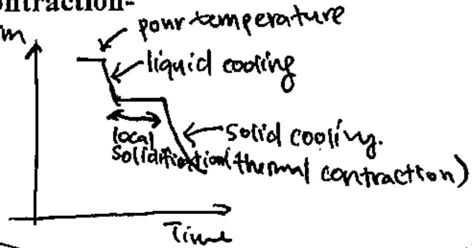
4.) suitable for ~~p~~ mass production.

(b) Shrinkages are often observed during solidification and cooling in sand casting processes. The shrinkages are caused by liquid contraction, solidification, and thermal contraction. Briefly describe the three phenomena, and give an example of what can be observed for each type of shrinkage.

(6 marks)

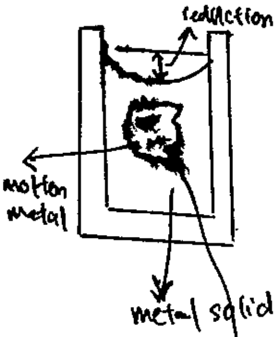


Liquid contraction-



The molten metal are initial poured at pouring temperature. Over time, A reduction in level cause by liquid contraction can be observed and as drawn. This is because as the temperature of molten liquid decrease, it's density increases. There are also abit of solidification at the wall

Solidification-

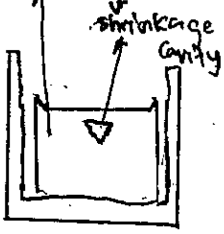


Continual cooling leads to a reduction in height and formation of shrinkage cavity caused by solidification.

This happen as the molten metal ~~transit~~ become solid state

Occurs in nearly all metals as the density of ~~w~~ solid phase is greater than liquid phase.

Thermal contraction-



Upon solidification. Solid metal continue to contract in it's solid state. Resulting in further reduction in volume during cooling of solid metal

Note : Question 1 continues on page 3.

(c) According to Chvorinov's rule, the total solidification time is related to the volume and surface area of the casting. If you want to reduce the total solidification time, how can you modify your casting? Justify your answers.

(4 marks)

$T_{TS} = C_m \left(\frac{V}{A}\right)^n$ accordiy to Chvorinov rule.

To reduce T_{TS} for a constant C_m. $\left(\frac{V}{A}\right)$ ratio should ~~be~~ be kept minimal

Alternatively change ~~casting~~ mold meterial to one with lesser C_m mold constant value.

(d) The Sheet Metal Working processes are generally classified into three categories: Bending operation, Deep or cup drawing, and Shearing. Briefly describe to differentiate each of these processes.

(6 marks)

Bending operation:

Bending is the forming of solid parts, where angled or ring-shaped workpiece are produced from sheet or strip metal.

a) It involves straining of sheet metal around a straight axis to take a permanent bend.

b) metal on the inside of the neutral plane is compressed, while the metal on the outside of the neutral plane is stretched. Consist of V-bending and Edge Bending.

Deep or cup drawing:

Drawing is the forming of smooth(sheet) blanks into hollow parts. sheetmetal form to make cup shape, box shaped or other complex-curved hollow-shaped parts. Sheet metal blank positioned over die cavity and then the punch pushes metal into the opening.

Shearing processes:

Shearing is cutting material without producing chips.

Consist of 3 principal operations, shearing, blanking, punching.

① shearing to separate large sheets

② Blanking to cut part perimeters outof sheetmetal.

③ Punching to make holes in sheet metal.

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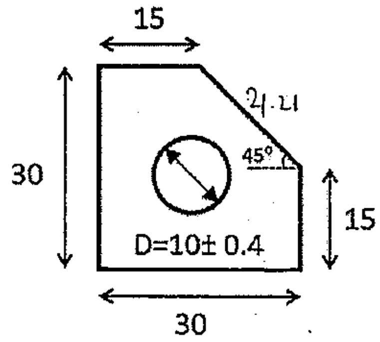
2. Blanking, Punching, and Measurement of Part Dimensions.
You are to design a compound die and punch to make a plate from cold-rolled steel sheet. The top view of the final product is shown below. The plate has a 45^0 sloped corner and a hole in the centre. The stock thickness is 4 mm. Given the allowance to be 0.075.



(All dimensions in mm)

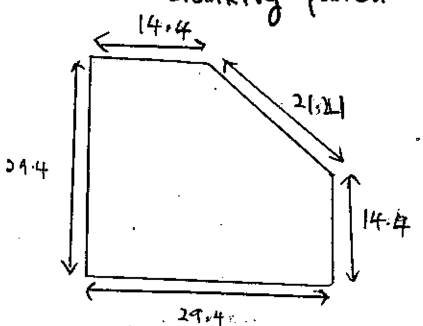
(a) Determine the punch and die sizes for the blanking operation. You can draw the punch and die and label the dimensions of all edges necessary.

(6 marks)

For the blanking operation: $C = at = 0.075 \times 4 = 0.3$ mm

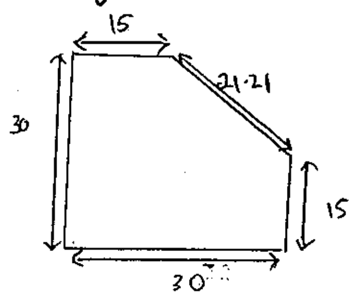
(All dimension in mm)

Blanking punch diameter



blank Punch diameter $= D_b - 2C$

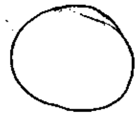
blanking die diameter

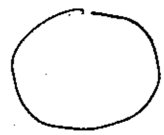


blank die diameter, $= D_b$

(b) Determine the punch and die sizes for the punching operation. You can draw the punch and die and label the dimensions of all edges necessary.

(6 marks)





Hole punch Diameter $D_h = 10 \pm 0.4$

Hole die diameter
$= D_h + 2c$
$= 10 \pm 0.4 + 0.6$
$= 10.6 \pm 0.4$

Note : Question 2 continues on page 5.

(c) What is the force required for the process if shear strength of the steel is 310 MPa?
(2 marks)

Cut Force = StL

$= 310\times10^6(0.004)(0.1962)$

$= 243288N$

$\approx 243.3kN$

$L = 30+30+15+15+21.21+\pi/4(10.4)^2$

$= 196.2mm$

(d) What tool will you use to inspect the hole diameter? What tool will you use to inspect the 45^0 angle?
(2 marks)

For the hole:

A Plug gage

For the angle:

Bevel protractor with vernier scale

(e) Given the wear allowance to be 2% of the entire tolerance band for the inspected feature, determine (i) the nominal size of the GO gage, and (ii) the nominal size of the NO-GO gage to inspect the hole diameter.
(4 marks)

i) Tolerance band = $0.4\times2 = 0.8mm$

wear allowance = $0.02(0.8) = 0.016mm$

$d_{final} = 9.6+0.016$

$= 9.616mm$

(Add material by making plug gage (Go gage bigger))

ii) $d_{nogo\ gage}$ = min material dimension

= 10.4mm (Biggest hole)

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3. Manufacturing of Plastic Products.
Here are some plastic products for manufacturing. What process will you use to make the product? Consider the volume that they are usually manufactured. Circle your answer.

(a) The plastic milk jug.

(2 marks)

Injection moulding / Blow moulding / Thermal forming / 3D printing

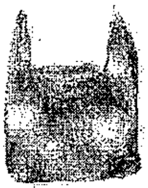
(b) The lid of the plastic milk jug.

(2 marks)

Injection moulding / Blow moulding / CNC machining / 3D printing

(c) Thin plastic bags.

(2 marks)



Injection moulding / Blow moulding / Extrusion / 3D printing

(d) Drinking straws

(2 marks)

Injection moulding / Blow moulding / Extrusion / 3D printing

Note: Question 3 continues on page 7.

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(e) Plastic cover for the telephone

(2 marks)

Injection moulding / Blow moulding / Extrusion / 3D printing

82.

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4 (a) Describe adhesive bonding and its advantages.

(3 marks)

Advantage:- Application to wide variety of material
- Sealing as well as bonding
- low temperature curing avoids damage to parts being joined

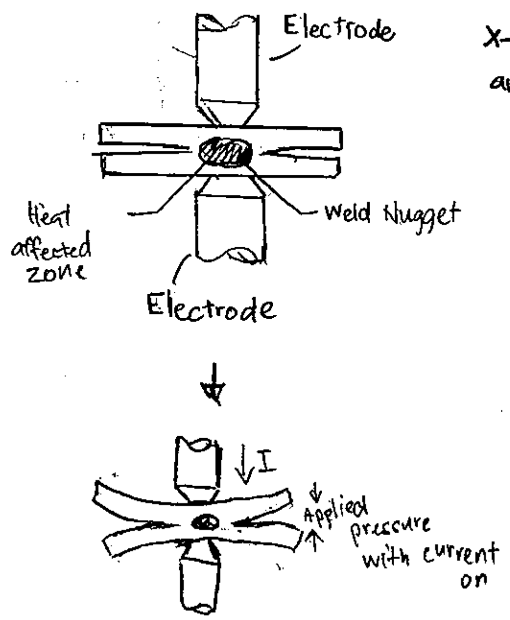
Disadvantage: Joints not as strong as other joining methods
Service temperature limited
& Inspection of bonded joint is difficult

(b) For automobile industry, recommend one process for sheet metal joining.

(i) Briefly describe the process step by step with sketches to show major process components.

(4 marks)

Recommend process: Resistance spot welding (RSW)



X-section of spot weld, showing weld nugget and indentation of electrode on sheet surfaces

A solid state welding (SSW) in which coalescence result from application of pressure and heat. The process involves usage of a supply electric current through the electrode as shown combined with high pressure load.

The melting is accomplished by heat from resistance to an electrical current between faying ~~Surfa~~ surfaces held together under pressure.

Note: Question 4 continues on page 9.

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(ii) What are the key factors that would affect the process? Justify your recommendation of the process.

(3 marks)

Key factors: Cleaness of faying surfaces and the ~~The 2 faying sur~~ ability to engage very close physical contact between faying surfaces to permit atomic bonding.

The process was ~~recond~~ recommended ~~be~~ as it can weld sheet metal quickly and Strongly for mass production of automotive-body. This make the vehicle more impact resistant.

Note: Question 4 continues on page 10.

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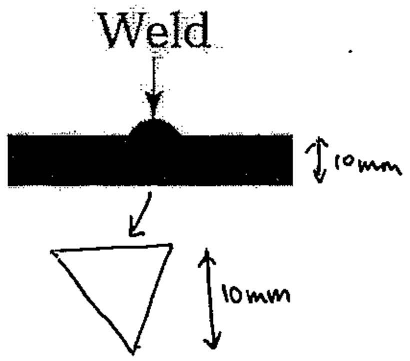
(c) A Gas Tungsten Arc Welding (GTAW) process is chosen to join two medium carbon steel plates with thickness of 10 mm. The cross-section of the welding area could be simplified as an equal sided triangle. The welding speed is 10 mm/s; the heat transfer factor is 0.7 and the melting factor is 0.65.

(i) Calculate the minimum of power requirement supply.

(4 marks)



$A_w = 10 \times 10 = 100 mm^2$ $\quad V = 10mm/s \quad f_1 = 0.70$

$WVR = A_w \times V = 1000 mm^3/s \quad f_2 = 0.65$

$U_m = KT_m^2$

$HR_w = U_m WVR = 1000 mm^3/s \times 9.6237 J/mm^3 \quad = 3.33 \times 10^{-6} (1700)^2$

$= 9263.7 \ J/s \quad = 9.6237 J/mm^3$

Note: Question 4 continues on page 11.

(ii) What is the possible cause for the following distortion after welding? (2 marks)

Cause of Angular dictortion is distortion caused by differential thermal expansion and contraction of different parts of welded assembly.

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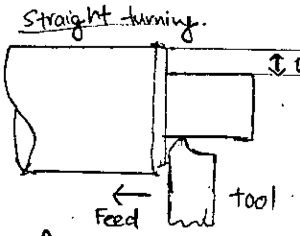
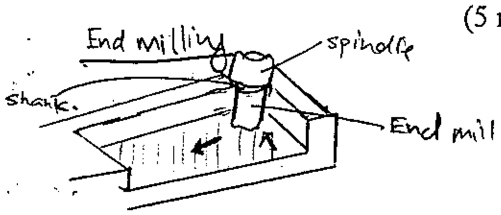
5 (a) Briefly describe two machining processes: straight turning and end milling. Draw sketches to illustrate major components of the two machining processes.

(5 marks)





As w/p rotates one revolution, a point on the w/p diameter D will move a distance of πD m
In N rev, the point will move πDN m.
In N rev/min, point will move πDN m/min

Cutter rotates on axis perpendicular to workpiece although it can be tilted to machine taper surfaces.

(b) What are the main sources of heat generation during cutting? Describe the adverse effects of temperature rise during cutting.

(5 marks)

Main sources of heat gen: ① Shear Zone - Shearing
② Tool-chip interface - Friction

Machine tool, workpiece and cutting tool may be affected

① Machine tool
→ Elevated and uneven temperature cause distortion of machine components.
→ Difficult to control dimensions.

② Workpiece
→ Uneven dimensional change in machine workpiece - difficult to control dimensional accuracy and tolerance.
→ Thermal damage to machined surface - part may fail before its expected life.

③ Cutting tool
→ strength, hardness and wear resistance may be affected.

Note: Question 5 continues on page 13.

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(c) Using a turning process, a metal rod diameter would be reduced from 50 mm to 48 mm with the turning speed of 1000 rev/min. The rake angle of the cutting tool used is 12 degree; the shear plane angle is estimated to be 35 degree; the cutting width is 6 mm. The undeformed chip thickness is 0.8 mm. The shear strength of the metal is 100 MPa.

(i) Calculate the cutting force (Merchant's equation is allowed).

(4 marks)

$D_o = 50mm$ $D_f = 48mm$

$N = 1000\ rev/min = 16.67 rev/s$

$\alpha = 12°$

$\phi = 35°$

width of cut $w = 6mm$

$t_o = 0.8mm$

$\tau = 100MPa$

$\phi = 45° + \frac{\alpha}{2} - \frac{\beta}{2}$ (Merchant Eqn)

$35° = 45° + \frac{12}{2} - \frac{\beta}{2}$

$\beta = 32°$ (Friction Angle)

$\tan\beta = \mu = \frac{F}{N}$

$F_c = \frac{\tau w t_o \cos(\beta - \alpha)}{\sin\phi \cos(\phi + \beta - \alpha)} = 1371N$

(ii) Calculate the cutting power required.

(3 marks)

$F_c \times V$

$V = \pi D_{avg} N = \pi(49mm)(16.67)\ mm/s$

$D_{avg} = \frac{D_o + D_f}{2}$ $= 2566W$

$= 49mm$

85

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6 (a) Describe the ion implantation process and its advantages.

(4 marks) / 17

Vaporized ions of impurity element are accelerated by an electric field and directed at silicon substrate.

→ Atoms penetrate into surface, losing energy and finally stopping at some depth in crystatal structure determined by mass of ion and accelerated voltage

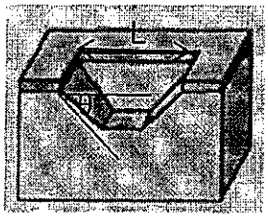
→ Advantages :

can be ~~ap~~ accomplished at room temperature
Provide exact doping density.

Note: Question 6 continues on page 15.

Official Use Only

(b) For a <100> silicon wafer, KOH wet etching was used in order to produce the following microstructure with etching depth of 2 μm. The window length L in the photomask is 10 μm.



(i) Calculate the angle θ

(4 marks)

$\theta = tg^{-1}(1) = 45°$

(ii) For the same microstructure, if the degree of anisotropy is 0.5, what is the window length in the silicon wafer?

(4 marks)

$A_f = 0.5$

~~B = L~~

$A_f = 1 - \frac{|B|}{2h_f}$

$0.5 = 1 - \frac{|B|}{2(2)(10^{-6})}$

$|B| = 2 \times 10^{-6}$

$|L - D_m| = 2 \times 10^{-6}$

$L > D_m$

$10 \times 10^{-6} - D_m = 2 \times 10^{-6}$

$D_m = 8 \mu m$

Note: Question 6 continues on page 16.

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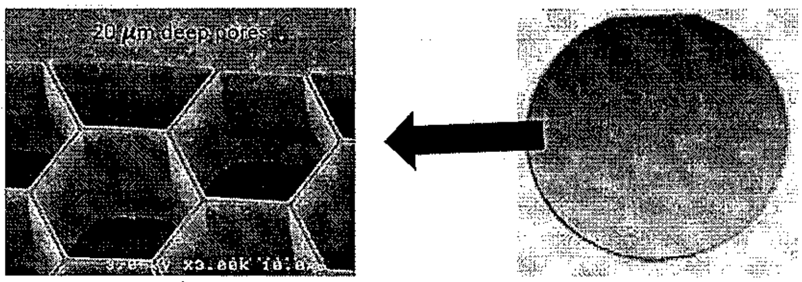
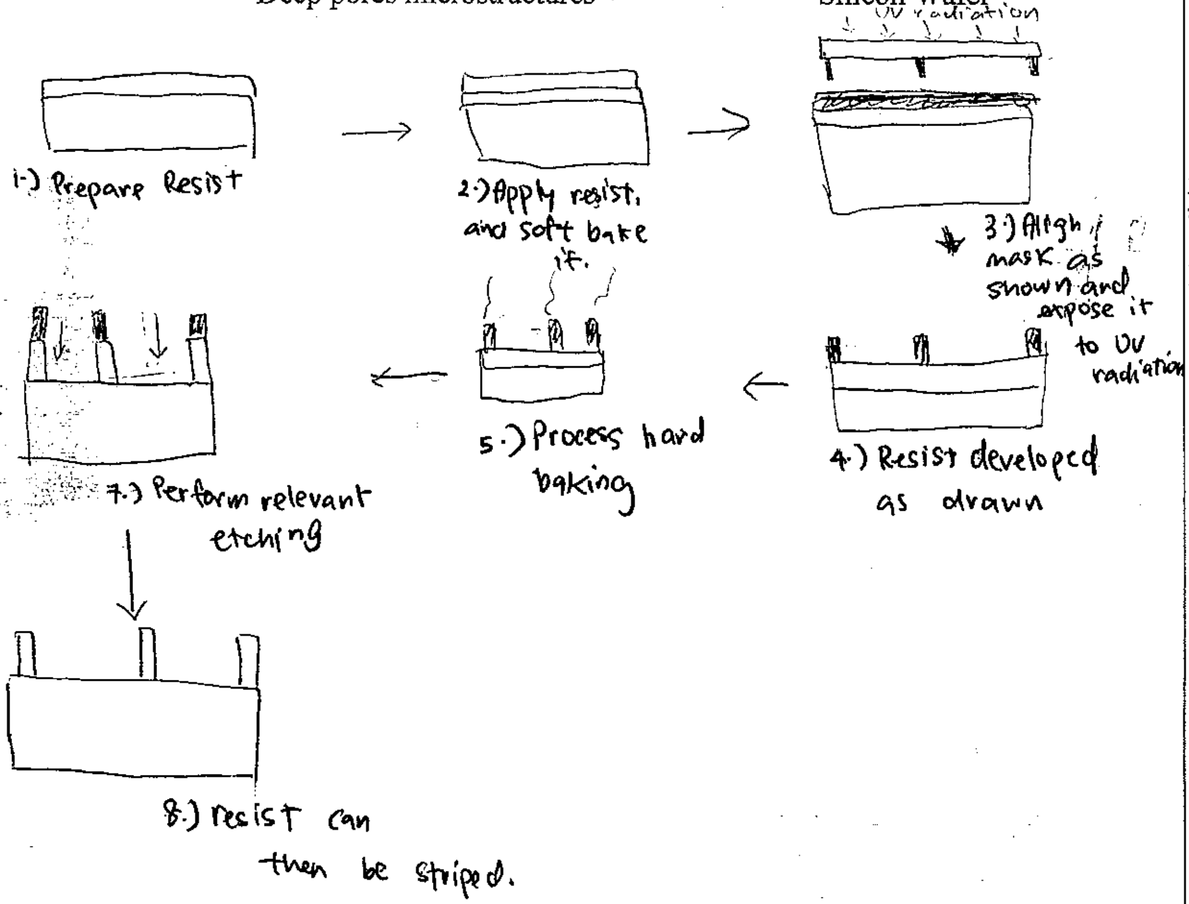
(c) In order to produce the following deep pore microstructure in a silicon wafer, what microfabrication process would you recommend? Briefly explain the microfabrication process step by step to generate the given microstructure from a silicon wafer.

(5 marks)



Deep pores microstructures

Silicon Wafer



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Appendix 1

You may find the following equations useful:

- Blanking and punching:

F= 0.7(*TS*)*tL*

- Deep drawing:

Bending Force: $F = \dfrac{K_{bf}(TS)wt^2}{D}$;

Drawing Force: $F = \pi D_p t(TS)\left(\dfrac{D_b}{D_p} - 0.7\right)$

Blank Holder Force: $F_h = \dfrac{0.015Y\pi}{4}\left\{D_b^2 - \left(D_p + 2.2t + 2R_d\right)^2\right\}$

TABLE 29.2 Melting temperatures on the absolute temperature scale for selected metals.

Metal	Melting Temperature °K[a]	Melting Temperature °R[b]	Metal	Melting Temperature °K[a]	Melting Temperature °R[b]
Aluminum alloys	930	1680	Steels		
Cast iron	1530	2760	Low carbon	1760	3160
Copper and alloys			Medium carbon	1700	3060
Pure	1350	2440	High carbon	1650	2960
Brass, navy	1160	2090	Low alloy	1700	3060
Bronze (90 Cu–10 Sn)	1120	2010	Stainless steels		
Inconel	1660	3000	Austenitic	1670	3010
Magnesium	940	1700	Martensitic	1700	3060
Nickel	1720	3110	Titanium	2070	3730

Based on values in [2].
[a]Kelvin scale = Centigrade (Celsius) temperature + 273.
[b]Rankine scale = Fahrenheit temperature + 460.

END OF PAPER

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NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2018-2019

MA2004 – MANUFACTURING PROCESSES

November/December 2018 Time Allowed: 2½ hours

Seat No.:

Matriculation No.:

INSTRUCTIONS

1. This paper contains **SIX (6)** questions and comprises **FOURTEEN (14)** pages.
2. Answer **ALL** questions.
3. Marks for each question are as indicated.
4. All your answers should be contained in this answer booklet and within the space provided after the question.
5. This is a **RESTRICTED-OPEN BOOK** examination (1 sheet of double-sided A4 reference paper is allowed).

Question No	Mark
1	
2	
3	
4	
5	
6	
Total	

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/ 20

1. **This question relates to sand casting.**

(a) Write down the names of parts A to H as indicated in Figure 1.

(8 marks)

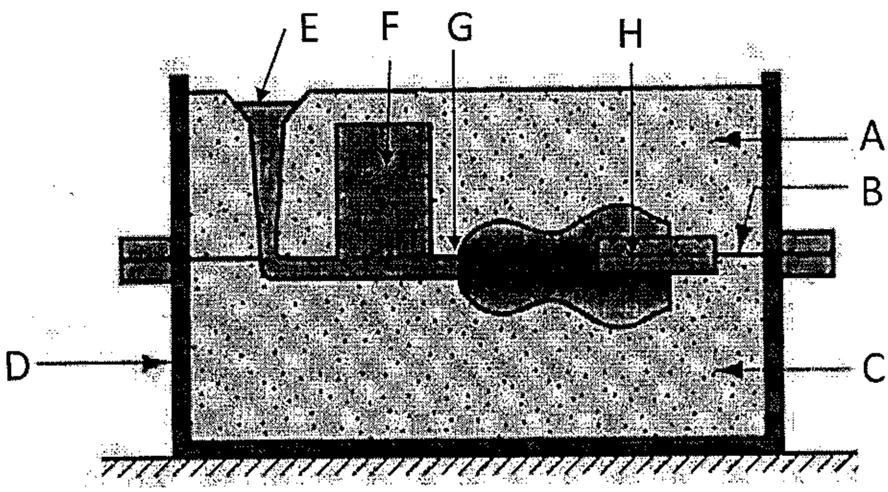

Figure 1

Write your answers in the table below.

Part	Name of the Part
A	
B	
C	
D	
E	
F	
G	
H	

Note : Question 1 continues on page 3.

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(b) What is the main function of part F and part H in Figure 1?

(4 marks)

Part F-

Part H-

(c) Explain what is fluidity in casting. Give <u>TWO</u> methods that can improve the fluidity in sand casting.

(4 marks)

(d) Give <u>TWO</u> examples of common defects in sand casting and explain how to avoid such defects.

(4 marks)

Note : Question 1 continues on page 4.

2. This question relates to design and manufacturing processes of a product.

You own a manufacturing workshop and you will make a cell phone/tablet holder for your customer, as shown in Figure 2. Your customer asked you to make 500 pieces of such holders. The holder will be made from aluminium alloy sheets with thickness of 3 mm. Your customer will sell this holder at SGD10 of retail price.

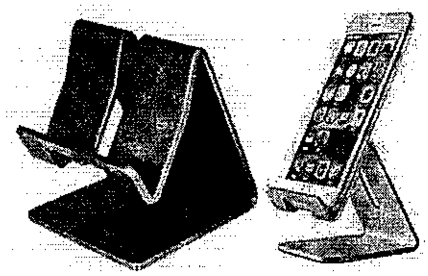

Figure 2: Cell phone holder

Now you are thinking of how to manufacture these holders in your workshop. You went to the stockroom and found many large 2024ST aluminium alloy sheets with thickness of 3 mm, so you decided to use them for the holders. You decided to first blank and punch the metal sheets to get the required dimensions, and then use V-bending to bend the blanked sheets for three times to its final shape. The dimensions of the blanked sheet before bending are shown in Figure 3 and the dimensions of the finished holder are shown in Figure 4.

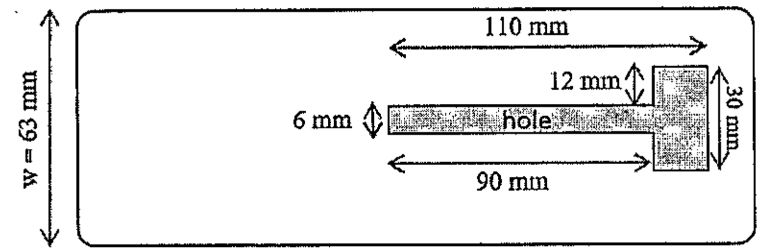

Figure 3: Aluminium alloy sheet before going through the bending process

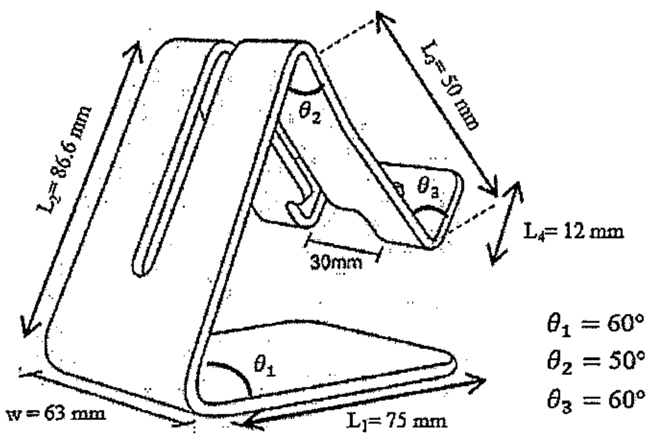

Figure 4: Detailed dimensions of the holder

Note : Question 2 continues on page 5.

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(a) The dimensions of the finished holder are shown in Figure 4. Given the bend radius to be 4 mm for all the three angles, determine the bend allowance for each of the three bended angles.

(3 marks)

(b) What is the starting blank size (length and width) required to make one holder? Use the lengths of straight portions (L_1, L_2, L_3, and L_4) given in Figure 4.

(3 marks)

Note : Question 2 continues on page 6.

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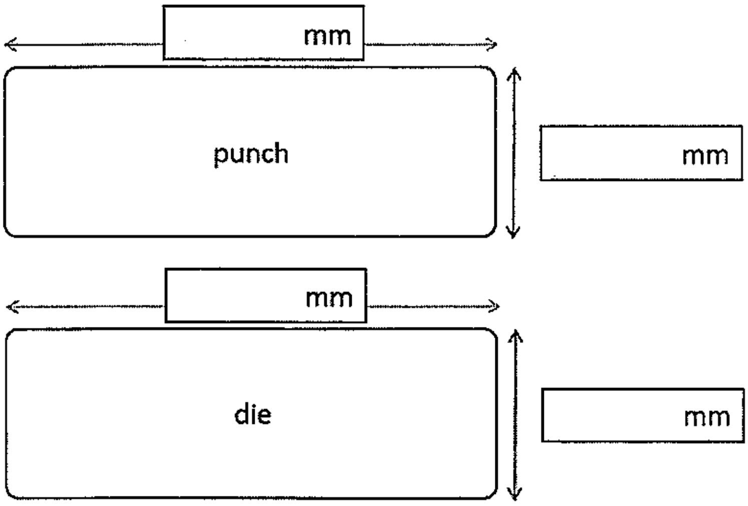
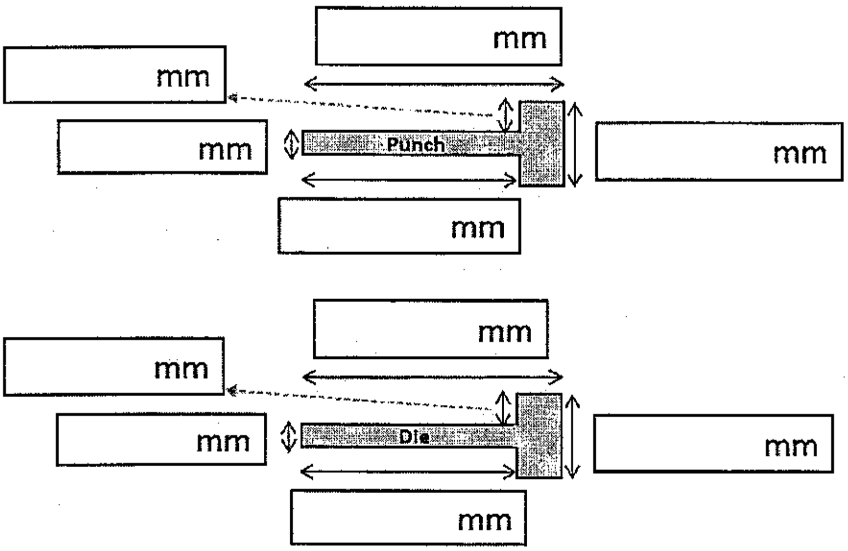
(c) Now you will design a "compound die" to simultaneously punch the hole and blank the perimeter to the required dimensions. Determine the die and punch dimensions of the compound die for the BLANKING process. The allowance a is 0.060 for 2024ST aluminium alloy. Use the starting blank size you calculated in (b) and the dimensions given in Figure 3. Give your answers by filling up the dimensions in the boxes below.

(2 marks)



(d) Continue from (c), determine the die and punch dimensions of the compound die for the PUNCHING process. Give your answers by filling up the dimensions in the boxes below.

(4 marks)



Note : Question 2 continues on page 7.

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(e) What is the force required for the compound die to cut the aluminium alloy sheet in order to obtain the punched and blanked sheet as shown in Figure 3? The tensile strength of the aluminium alloy is 350 MPa.

(3 marks)

(f) Given the V-die opening to be 40 mm, calculate the force required for bending the 50^{0} angle.

(3 marks)

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3. Give short answers to the following questions.

(a) Explain precision and accuracy in dimensional measurement.

(4 marks)

(b) List one common defects in polymer injection moulding and how to avoid it.

(3 marks)

(c) List TWO products that can be made by blow moulding.

(2 marks)

(d) Why does wear allowance only apply to Go limit for both snap gage and plug gage?

(3 marks)

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/ 15

4. **This question relates to welding and joining processes.**

(a) What is the name of the type of welded joint shown in Figure 5? In your judgement, is the weld shown in the figure produced by a fusion welding process or solid-state welding process? Do you need to use shielding gas in the welding process? Give your reasons.

(5 marks)

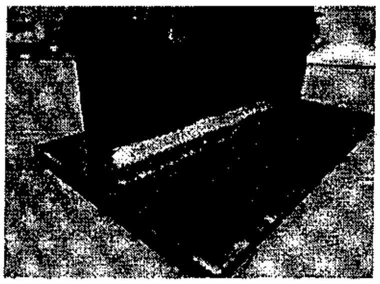

Figure 5

(b) Both galvanized steel and aluminium alloy are used in manufacturing of car structures, so joining between the two materials sometimes becomes necessary, as illustrated in Figure 6. If the joining is carried out by a fusion welding process using arc or laser as the heat source, what would be the potential problems? In your opinion, is it feasible to carry out the joining process using an arc by carefully controlling heat input from the arc to melt the aluminium alloy only (i.e., the steel is not melted)? Give your reasons.

(5 marks)

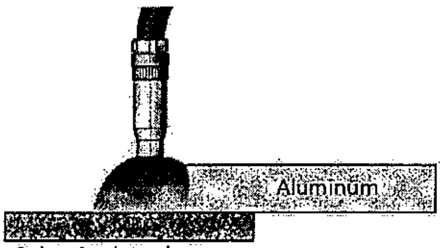

Figure 6

Note : Question 4 continues on page 10.

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(c) What is heat transfer efficiency? What is melting efficiency? Are heat transfer efficiency and melting efficiency very high for an electrical resistance spot welding process? Give your reasons.

(5 marks)

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/ 20

5. This question relates to machining processes.

(a) What is the name of the machining process shown in Figure 7? Which are the basic properties required for the cutting tool material? Give your reasons.

(5 marks)

Cutter

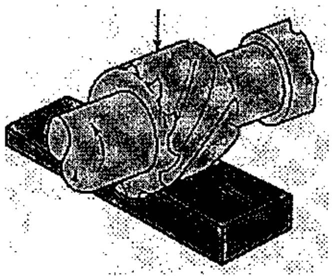

Figure 7

(b) Figure 8 illustrates the use of cutting fluid in a machining process. Is the cutting fluid properly applied? Why do you think so? What are the major reasons for applying cutting fluid in machining processes?

(5 marks)

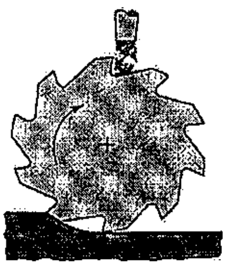

Figure 8

Note : Question 5 continues on page 12.

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(c) What is a turning process? If a severely oxidized cylindrical component of highly alloyed steel needs to be turned on a lathe, would you recommend a large depth of cut? Give your reasons.

(5 marks)

(d) Draw a force diagram of an orthogonal cutting operation and clearly identify the following forces and angles in the diagram: cutting force F_c, thrust force F_t, shear force F_s, friction force F, rake angle α, friction angle β and shear angle φ. Calculate the friction angle β given that $F_c = 240$ N, $F_t = 95$ N and $F = 130$ N.

(5 marks)

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/ 15

6. **This question relates to microelectronics manufacturing.**

(a) What is the name of the manufacturing process shown in Figure 9? What is its end product? Briefly describe the manufacturing process.

(5 marks)

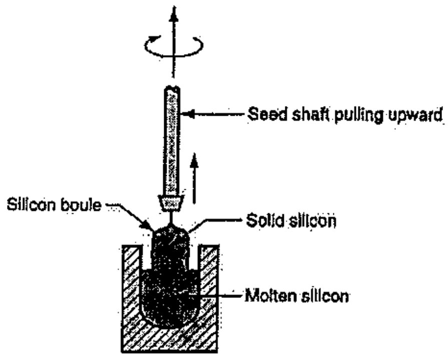

Figure 9

(b) What is the meaning of lithography in a microelectronics manufacturing process? What are the major differences between photolithography and ion lithography?

(5 marks)

Note : Question 6 continues on page 14.

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(c) Show the step-by-step procedures for fabricating the structure in a silicon wafer as illustrated in Figure 10.

(5 marks)

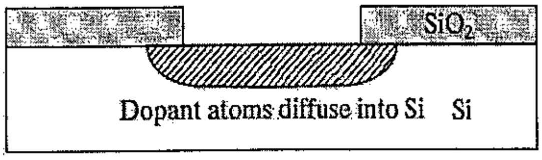

Figure 10

END OF PAPER

No. 18/19 Sem 1 MA2004 Date:

Part	Name of Part
A	cope
B	drag
C	parting line
D	flask
E	pouring cup
F	riser
G	gate
H	core

1b) Part F – riser serves as a reservoir of molten metal, and is designed to freeze after main casting solidifies. It reduces solidification shrinkage by supplying additional liquid metal to casting.

Part H – Liquid metal surrounds and freezes over the core. As a result, interior geometry of casting is determined by shape and surface pattern of core. In fig1, a hollow cylindrical shape is formed.

c) fluidity is the ease at which molten liquid flows, and is the inverse of viscosity. Fluids with high fluidity flow into cavity at a faster rate and is more likely to fill entire cavity before freezing (preventing misruns).
Fluidity can be increased by raising pouring temperature of molten liquid relative to melting point and restricting size of gating channel to increase pressure at which liquid enters cavity.

d) i) misruns occur when molten metal freezes before completely filling cavity. Can be avoided by increasing pouring temperature of liquid.

ii) Mold erosion occurs when pouring is done too rapidly, and results in molding sand being incorporated into the casting, which weakens material properties. Can be avoided by reducing pouring rate / ensuring mold is rammed.

2a) $A_{b_1} = 2\pi \frac{\alpha}{360}(R + K_{ba} t)$, where α is bend angle

$K_{ba} = \begin{cases} 0.33 \text{ if } R < 2t \\ 0.5 \text{ if } R >= 2t \end{cases}$

for angle 1: $A_b = 2\pi \frac{120}{360}(4 + 0.33 \times 3) = 10.45$ mm

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Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2lW2C32

for angle 2 : $A_{b_2} = 2\pi \frac{130}{360} [4 + 0.33 \times 3] = 11.322mm$

since parameters of angle 3 is same as angle 1, Ab for angle 3 = 10.451mm

b) starting blank length: $75 + 10.451 + 86.6 + 11.322 + 50 + 10.451 + 12$

$= 255.82mm.$

starting blank width = 63mm

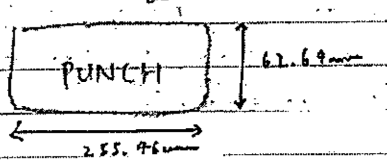
c)

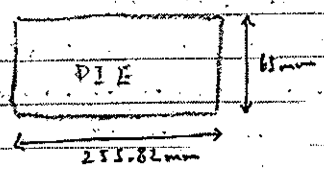
$D_{blank} = D_{die}$

$= 2c + D_{punch}$ (or D_{hole})

where $c = at$

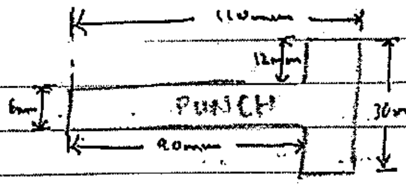
$\therefore D_{punch} = D_{blank} - 2(0.06 \times 3mm)$

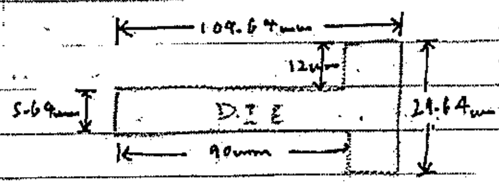


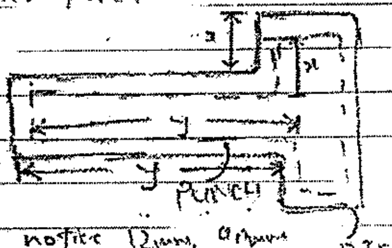


for complex shapes; draw die outline, then punch

d)







notice 12mm, 90mm are unchanged

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e) Neglecting clearance effects and assuming entire length of cut made simultaneously:

$F = StL = 0.7\,TS\,tL$ (hole perimeter)

$= 0.7 \times 350 \times 3 \times [2 \times 63 + 2 \times 255.82 + 220 + 60]$ (blank perimeter)

$= 674\,kN$

f) note that length ≠ 63mm due to hole.

$F = \frac{1.33\,(350)\,57 \times 3^2}{40} = 5.97\,kN$

3a) Precision: degree of repeatability in measurement process. High precision reduces random errors. Precision can be improved using measuring instruments with small resolution, or taking average readings.

Accuracy: degree to which measured value agrees with actual value of quantity of interest. High accuracy reduces systematic errors. Accuracy can be improved through isolating effects of all but one variable.

b) Short shots occur when molding solidifies before completion, and can be avoided by increasing pumping temperature & pressure.

c) plastic water bottles & watering cans.

d) Go limit measures and checks for maximum material condition. Due to wear and tear, go limit can allow for parts exceeding maximum material condition to be deem acceptable, hence wear allowance is required.

wear allowance is not needed for no-go limit as although wastage occurs when acceptable parts are deemed unacceptable, faulty parts will never be approved.

4a) Tee joint. Fusion welding process. Shielding gas is required. At high temperatures, molten metals can react with atmospheric gases to form oxides which degrade metallic properties. Shielding gas (and trailing

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gas) provides a protective envelope to prevent ~~reaact~~ reaction.

b) If fusion welding is used and both steel and aluminium melts, very brittle intermetallic structures will form, which severely degrade structural strength. However, if amount of heat applied is controlled to only melt aluminium (fusion welding with respect to aluminium but solid state with respect to steel), aluminium can be joined with steel. This is currently in use in automobile industry.

c) Heat transfer efficiency: ratio of energy received by work piece over total energy generated. Rest is lost to surroundings.
Melting efficiency: ratio of energy used for melting over total energy received by work piece. Rest is conducted away to work piece / machinery / holder.
For resistance spot welding: heat transfer efficiency is high as no contact with surrounding atmosphere means little heat is lost to surrounding air. However, melting efficiency is slightly lower due to 2 metallic parts serving as large heat sinks, rapidly conducting heat away.

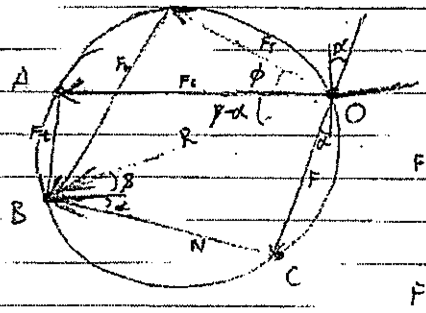
5a) milling. It is a form of interrupted cutting process. High toughness is required to prevent tool from chipping upon contact, and thermal shock resistance and hot hardness is required to ensure tool does not deform at temperature rise, which leads to poor dimensional accuracy. Wear resistance and chemical inertness are required to prevent poor surface finish.

b) No cutting fluid should be applied at point of contact between tool and workpiece. This is because i) fluid is unable to reach workpiece and fulfill its functions, such as washing away chips, and ii) putting fluid at top subjects cutting tool to extreme temperature fluctuations every cycle. Reasons for cutting fluid: act as lubricant to reduce friction, act as coolant to reduce temperature, wash away chips to prevent interference.

c) Turning is a cutting process where work piece rotates at high speeds while a cutting tool ~~move~~ moves along the longitudinal axis to reduce the diameter of the work piece

5c) Large depth not recommended. Alloyed steel is very hard, tool is likely to experience significant chattering in cutting hard surface. Additionally, by extended Taylor's tool life equation, $VT^n d^x f^y = C$, tool life is likely to be very short, need continuous replacement, incur high costs. Recommend instead using chemical etching to remove hard oxide layer first, followed by shallower depth etching.

5d)



$F_c = 240N$

$F_t = 95N$

$F = 130N$

From triangle OAB:

$\tan(\beta - \alpha) = \frac{F_t}{F_c}$ $\therefore (\beta - \alpha) = 21.59°$ —①

$R = \sqrt{F_c^2 + F_t^2} = 258.12N$

From OBC:

$\sin(\beta + \alpha) = \frac{F}{R} = \frac{130}{258.12}$ ~~= 30.24~~

$\therefore \beta + \alpha = 30.24$ —②

From ① and ②: $\beta = 25.9°$

6a) Growing single crystal through Czochralski process. End product: large boule of single Silicon crystal. Electronic grade silicon is heated and melted. A rotating shaft with single grain of silicon acts as nucleation site. Shaft is dipped into molten silicon. Shaft is rotated and pulled out slowly. Single crystal with unit cell oriented in same direction is obtained.

b) Lithography: process where electro layers are removed and etched.
Photo lithography uses light to cure photoresist while Ion lithography uses ions.
Ion lithography has higher resolution as ions diffuse less.

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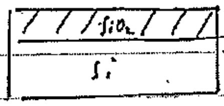
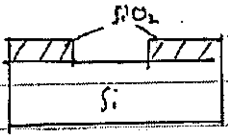
Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

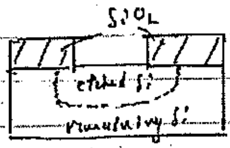
c)



Silicon wafer undergoing wet thermal oxidation
$Si + 2H_2O \rightarrow SiO_2 + 2H_2$

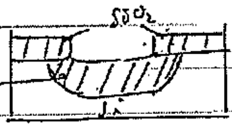


apply photoresist and carry out photolithography to etch away SiO_2 in centre



use chemical etching (isotropic) to remove Si in centre, while leaving SiO_2 in place

dopant



use ion implantation / thermal diffusion to dope ions into Si. Remove top layer of SiO_2 by etching if necessary.

All the Best!

NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2019-2020

MA2004 – MANUFACTURING PROCESSES

November/December 2019 Time Allowed: 2½ hours

Seat No.:

Matriculation No.:

INSTRUCTIONS

1. This paper contains **SIX (6)** questions and comprises **FOURTEEN (14)** pages including **ONE (1)** page of Appendix.
2. Answer **ALL** questions.
3. Marks for each question are as indicated.
4. All your answers should be contained in this answer booklet and within the space provided after the question.
5. This is a **RESTRICTED-OPEN BOOK** examination (1 sheet of double-sided A4 reference paper is allowed).

Question No	Mark
1	
2	
3	
4	
5	
6	
Total	

98

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1. A plastic washer manufacturer has been producing ABS washers for its customer. The outer diameter of the washer is 3.25 ± 0.02 cm, the inner diameter of the washer is 1.50 ± 0.015 cm, and the thickness of the washer is 2 mm.

(a) Design a GO/NO-GO gauge to check the outer diameter, given the wear allowance to be 2% of the entire tolerance band. Make a sketch of the gauge and indicate the required dimensions.

(4 marks)

Tolerance = 0.04

Wear allowance = 0.02 × 0.04 = 8×10^{-4} cm

~~GO diameter = 3.25 − 0.02 − 8×10^{-4}~~

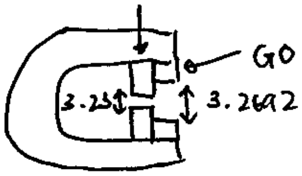
~~= 3.2292 cm~~

NO-GO diameter = 3.25 − 0.02

= 3.23 cm

GO diameter = 3.25 + 0.02 − 8×10^{-4}

NO GO = 3.2692 cm



(b) Design a GO/NO-GO gauge to check the inner diameter, given the wear allowance to be 3% of the entire tolerance band. Make a sketch of the gauge and indicate the required dimensions.

(4 marks)

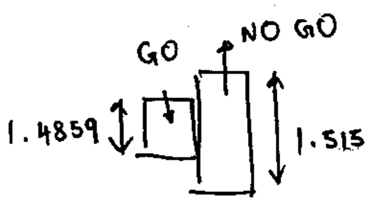
Tolerance = 0.03

Wear Allowance = 0.03 × 0.03 = ~~8.~~ 9×10^{-4} cm

GO diameter = 1.50 − 0.015 + 9×10^{-4}

= 1.4859 cm

NO GO diameter = 1.50 + 0.015 = 1.515 cm



Note : Question 1 continues on page 3

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(c) If the manufacturer has a few ABS long rods in stock, and the diameter of the rod is 3.5 cm, suggest a manufacturing process sequence to reach the final washer shape and required dimensions.

(4 marks)

Use a lathing machine to reduce outer diameter from 3.5 to 3.25

Use a drill to drill a hole of 1.50cm diameter

Use lathing machine to cut the rods into 2mm thickness.

(d) If the manufacturer receives a large order to produce 10,000 of such ABS washers, what will be a better manufacturing process over the process you suggested in question (c)?

(3 marks)

Use an injection molding process.

Melt the ABS rod and use the injection molding process to form the washers.

This process is better as the process is automated compared to CNC machining which takes a long time.

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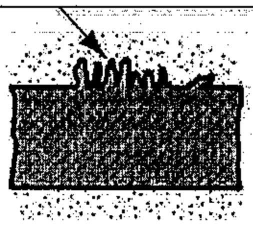
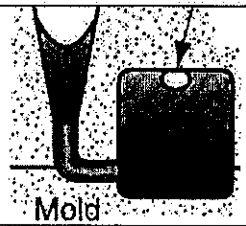
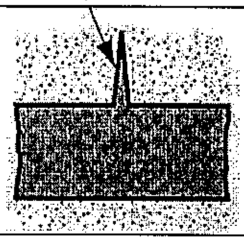
2. **This set of questions is about casting processes.**

(a) Name the following defects of a part made by sand casting. Explain the reason for each of the defects and how to avoid occurrence of the defect.

(9 marks)

Defect Name	Reason for the defect	How to avoid
 Penetration	High fluidity of metal penetrates sand core	Reduce fluidity by changing metal or reducing pouring temperature.
 Sand Blow	Balloon shaped gas cavity forms as mold gas released during casting	Reduce pouring rate to allow air to escape or change mold design to allow gas to escape
 Mold Crack	Crack develops in mold and liquid metal seeps in	Ensure mold isn't crack before casting. Increase density of sand mold.

(b) A foundry man wants to estimate the solidification time for two castings. In a casting process, casting A is an aluminium cube with the length of the edge = H cm. Casting B is a zinc sphere with diameter = H cm. The total solidification time of casting A is 95 seconds. Given the exponent n in the Chvorinov's rule to be 2, determine the solidification time for casting B.

(2 marks)

$\frac{V}{A}$ of cube $= \frac{H^3}{6H^2} = \frac{H}{6}$

$\frac{V}{A}$ of sphere $= \frac{\frac{4}{3}\pi\left(\frac{H}{2}\right)^3}{4\pi\left(\frac{H}{2}\right)^2} = \frac{H}{6}$

Since $\frac{V}{A}$ same, solidification time $= 95s$

Note : Question 2 continues on page 5.

(c) A flat aluminium plate is to be cast in an open mould whose bottom has a square shape. The mould is 40 mm deep. Solidification shrinkage is known to be 6.0%, which is a volumetric contraction, not a linear contraction. Linear shrinkage due to solid thermal contraction is known to be 1.4%. The availability of molten metal in the mould allows the square shape of the cast plate to maintain its bottom dimensions to be the same as the bottom of the square mould until solidification is completed. If the final dimensions of the plate will be L x L x H = 200 mm x 200 mm x 25 mm, determine:

(i) The bottom dimension of the square mould.

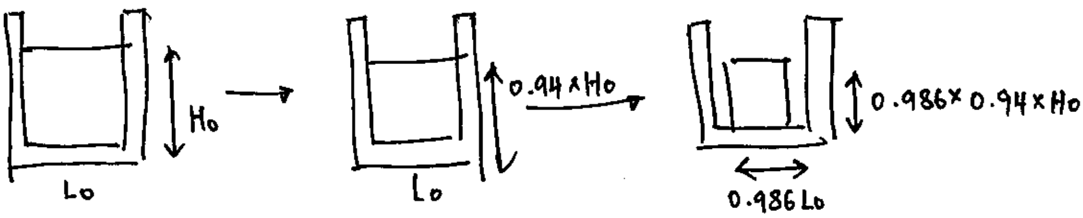
(3 marks)

(ii) The initial volume of molten metal.

(3 marks)

(iii) The starting height of the molten metal right after pouring into the open mould.

(3 marks)



i) $200 = 0.986\,L_o$

$L_o = 202.839$ mm

ii) $25 = 0.986 \times 0.94 \times H_o$

$H_o = \frac{25}{0.986 \times 0.94}$

$= 26.9733$ mm

Volume $= 202.8939^2 \times 26.9733$

$\simeq 1110381$ mm^3

iii) $H_o = 26.9733$ mm

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3. **This set of questions is about sheet metalworking.**

(a) In order to perform a successful shearing process, the clearance, which is the distance between punch and die, needs to be determined. What are the TWO factors to determine the correct clearance?

(2 marks)

$c = at$

Allowance and sheet thickness is needed for correct clearance

(b) A round disk of 200 mm diameter is to be blanked from a 2 mm thick brass sheet. Determine the punch and die dimensions for the blanking process.

(2 marks)

$a = 0.060$

$t = 2$

$D_b = 200\text{mm}$

$D_p = 200 - 2(0.060)(2)$

$= 199.76 \text{ mm}$

(c) The blanked disk in question (b) is to be drawn into a cup with a maximum drawing ratio of 2.0. Estimate the minimum possible cup diameter that can be drawn.

(2 marks)

$$DR = \frac{D_b}{D_p}$$

$$2 = \frac{200}{D_p}$$

$D_p = 100\text{mm}$

Note : Question 3 continues on page 7.

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(d) Using the minimum cup diameter in question (c), estimate the final cup height of the drawing process.

(3 marks)

Blank Volume = Cup volume

$$\pi\left(\frac{200^2}{4}\right)(2) = \pi(100)(h)(2) + \pi\frac{(100^2)}{4}(2)$$

$$h = \frac{\pi\left(\frac{200^2}{4}\right)(2) - \pi\frac{(100^2)}{4}(2)}{\pi(200)}$$

$$= 100 - 25 = 75\text{ mm}$$

(e) After drawing the cup, you found some tearing cracks in the vertical wall. Why does the tearing occur and how can you prevent it from happening?

(3 marks)

Longitudinal tensile stress during drawing causes tearing cracks.

Reduce the blankholder force to reduce tearing.

(f) Using the round disk blanked in question (b), a V-bending through the centre of the disk was done to create a 90° angle. Calculate the bending force required. The tensile strength of the material is 370 MPa and the die opening dimension = 30 mm.

(3 marks)

$$\text{Bending force} = \frac{K_{bf}(TS)wt^2}{D}$$

$$= \frac{1.33(370\times10^6)(200\times10^{-3})(2\times10^{-3})^2}{30\times10^{-3}}$$

$$= 13122\text{ N}$$

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4. **This question relates to welding and joining processes.**

(a) What is the name of the welding process shown in Figure 1? Is this a fusion welding or solid-state welding process? Is shielding gas usually used in the welding process? Give your reasons.

(5 marks)

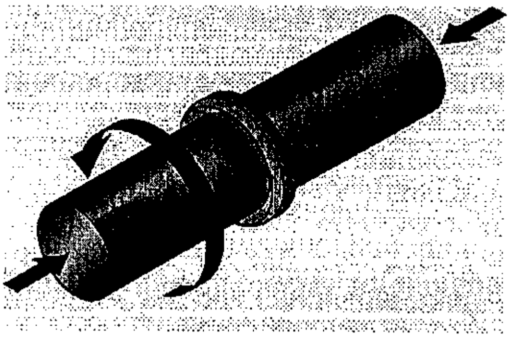

Figure 1

Friction Welding.
Solid state process as metal joins from pressure and heat and if heat is used, temperature is below melting point of metals. No shielding gas is needed as low temperatures do not allow metal to bond with the molecules in the air.

(b) What is melting efficiency? Which of the following welding processes has the lowest melting efficiency: oxyfuel gas welding, tungsten inert gas welding, submerged arc welding, and electrical resistance spot welding? Give your reasons

(5 marks)

Propotion of heat used for melting while the rest is conducted away from metal. I think that electrical resistance spot welding has the lowest melting efficiency as the heating element directly contacts the metal plates and thus heat is able to be conducted away quicker, lowereng melting efficiency.

Note : Question 4 continues on page 9.

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(c) Is it correct to state that the unit melting energy of a metallic material is usually proportional to its melting point? Calculate unit melting energy of the workpiece material in an arc welding process if the following can be assumed: welding voltage E = 23 V, welding current I = 165 A, heat transfer efficiency f_1 = 0.75, melting efficiency f_2 = 0.78, welding speed v = 150 mm/min, and cross-sectional area of the weld A_w = 80 mm^2.

(5 marks)

Yes it is. The formula for unit melting energy is $U_m = K T_m^2$, therefore, the higher the melting temperature, the higher the unit melting energy.

$V = 150$ mm/min
$= 2.5$ mm/s

$f_1 f_2 V I = v A_w U_m$

$$U_m = \frac{0.78 \times 0.75 \times 165 \times 23}{2.5 \times 80}$$

$= 11.100$ J/mm^3

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5. **This question relates to machining processes.**

(a) What are the types of chips produced in the cutting of very ductile materials? Which type of chips gives the poor surface finish? Give your reasons.

(6 marks)

Continuous chips are produced in cutting of very ductile materials. Built up edge and serrated chips give poor surface finish. Built up edge is formed as layers of workpiece material deposited, becoming unstable and then breaking up eventually, giving poor surface finish. Serrated chips are formed by metals with low thermal conductivity and strength that decreases sharply with temperature giving irregular surface finish.

(b) What are the most important physical and chemical properties of a cutting tool? Do you expect the properties of a cutting tool to affect the specific energy of the workpiece material it cuts? Give your reasons.

(6 marks)

The most important physical and chemical properties are hot hardness, toughness, thermal shock resistance, wear resistance, chemical stability and inertness.

I do not expect the properties of a cutting tool to affect the specific energy of the workpiece material it cuts. This is because the specific energy is dependent on the strength of the material. Its strength is not affected by the cutting properties of the tool used.

Note : Question 5 continues on page 11.

(c) The diameter of a cylindrical workpiece is reduced from 100 mm to 92 mm by turning on a lathe in a single pass. The length of cut is 500 mm, the spindle rotates at 400 rev/min, and the cutting tool travels at a linear speed of 200 mm/min along the workpiece length. Calculate the machining time. If the specific energy of the workpiece material is 3.2 W·s/mm^3, calculate the minimum power of the lathe.

(8 marks)

$$t = \frac{500}{200} = 2.5 \text{min}$$

Total Amount of Material removed:

$$\left(\frac{\pi(100)^2}{4} - \frac{\pi(92)^2}{4}\right) \times 500$$

Total Energy:

$$\left(\frac{\pi(100)^2}{4} - \frac{\pi(92)^2}{4}\right) \times 500 \times 3.2$$

Power:

$$\frac{\left(\frac{\pi(100)^2}{4} - \frac{\pi(92)^2}{4}\right) \times 500 \times 3.2}{~~3.2~~ ~~2.5~~ \cdot 2.5 \times 60}$$

$= 12867 \text{w/s}$

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6. **This question relates to microelectronics manufacturing.**

(a) What is the name of the microelectronics manufacturing process shown in Figure 2? Briefly describe the process. Is this manufacturing process suitable for mass production?

(5 marks)

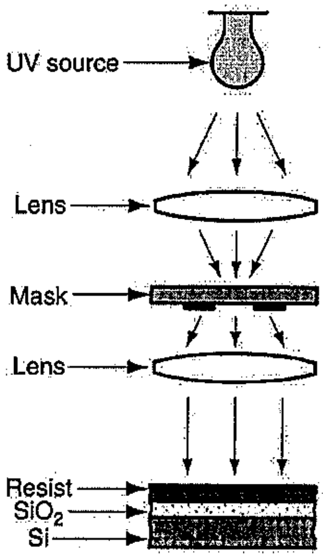


Figure 2

The process is called projection printing. The mask contains pattern that is to be transferred onto the resist. The UV source is turned on and certain areas are exposed to the UV rays per the design. The exposed area are then more soluble and can be etched away. This manufacturing process is suitable for mass production as it projects high definition images while preventing the mask from contacting the resist, preventing wear and tear.

(b) Briefly describe the role played by photoresist in microelectronics manufacturing processes. Is it possible to carry out the microelectronics manufacturing processes without using any photoresist? Give your reasons.

(5 marks)

A photoresist is an organic polymer that is sensitive to light in a certain wavelength range. This allows the resist exposed to be more soluble.

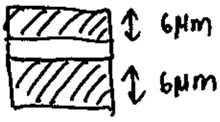
I do not think that is possible to carry out the process without any photoresist. This is because most of manufacturing process are layering process and hence a photoresist is needed to transfer the pattern onto the photoresist.

Note : Question 6 continues on page 13.

(c) Two sides of a circular disk of 100 mm in diameter are nickel plated in an electrolyte bath using a direct current of 10 A. Calculate the cathode efficiency if the plating constant is 3.5×10^{-5} cm^3/A·s and it takes 4.8 min to attain a 6 μm thick nickel layer.

(5 marks)

$V = ECIt$



$100\text{ mm} = 10\text{ cm}$

$6\mu m = 6\times10^{-4}\text{ cm}$

$$E = \frac{V}{CIt}$$

$$= \frac{12\times10^{-4}\times\pi\times\left(\frac{10^2}{4}\right)}{3.5\times10^{-5}\times10\times4.8\times60}$$

$$= 0.9349$$

Appendix

You may find the following formulae useful:

- Bending Force: $F = \frac{K_{bf}(TS)wt^2}{D}$, K_{bf}=1.33 for V-bending, K_{bf}=0.33 for edge bending
- Drawing Force: $F = \pi D_p t(TS)\left(\frac{D_b}{D_p} - 0.7\right)$
- Blank Holder Force: $F_h = \frac{0.015Y\pi}{4}\left\{D_b^2 - \left(D_p + 2.2t + 2R_d\right)^2\right\}$

Table 1. Allowance values of common metals for shearing processes.

Metal Group	Allowance a
1100S and 5052S aluminum alloys, all tempers	0.045
2024ST and 6061ST aluminum alloys; brass, soft cold rolled steel, soft stainless steel	0.060
Cold rolled steel, half hard; stainless steel, half hard and full hard	0.075

END OF PAPER