NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2022-2023

MA2024 – ENGINEERING MATERIALS AND MANUFACTURING PROCESSES

April/May 2023 Time Allowed: 2½ hours

Seat No.:

Matriculation No.:

INSTRUCTIONS

1. This question and answer booklet 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. One double-sided A4-size reference sheet with texts handwritten or typed on the A4 paper (no sticky notes/post-it notes on the reference sheet) is allowed.

For examiners:

Questions	**1** (15)	**2** (20)	**3** (15)	**4** (16)	**5** (18)	**6** (16)	**Total** (100)
Marks							

Q1. (15 marks)

/15

Crystallinity of solids

(a) Draw the following plane and direction in cubic unit cells.

(6 marks)

(i) $(1\bar{2}0)$

(ii) $[\bar{3}10]$

Solution:

(b) Calculate the planar density of (110) plane in tungsten, which is BCC structure with atomic radius of 0.210 nm.

(3 marks)

Solution:

Note: Question 1 continues on page 3.

(c) Calculate the atomic packing factor of an FCC unit cell.

(3 marks)

Solution:

(d) Calculate the theoretical density of copper. Copper is FCC structure, with atomic radius of 0.128 nm and atomic weight of 63.546 g/mol. Avogadro's number is 6.023 x 10^{23} atoms/mol.

(3 marks)

Solution:

Q2.(20 marks)

/20

(a) Refer to the phase Cu-Ag phase diagram in Figure 1. The composition of a Cu-50%-Ag alloy was cooled from 1000ºC to room temperature.

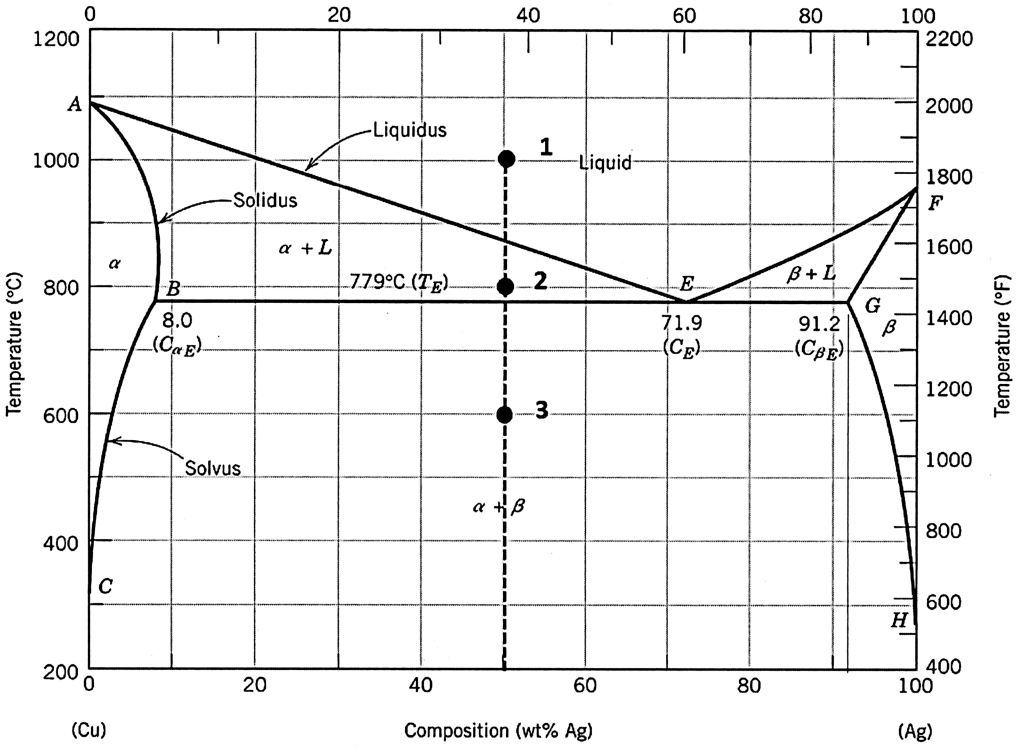


Figure 1

(i) Draw the microstructures of the alloy at point 1 (1000 ºC), 2 (800 ºC), and 3 (600 ºC).

(5 Marks)

Solution:

Note: Question 2 continues on page 5.

(ii) Find the composition of the first formed solid phase. Also, find the composition of the last remaining liquid phase.

(5 Marks)

Solution:

(iii) Determine the mass fraction of primary α, eutectic α, and eutectic β at 600ºC.

(10 Marks)

Solution:

/15

Q3. (15 Marks)

Mechanical Properties of metals.

(a) Figure 2 shows the stress-strain curve of 3 different engineering materials. Fill in the ranks in the table 1 of the following properties among the three materials.

(5 Marks)

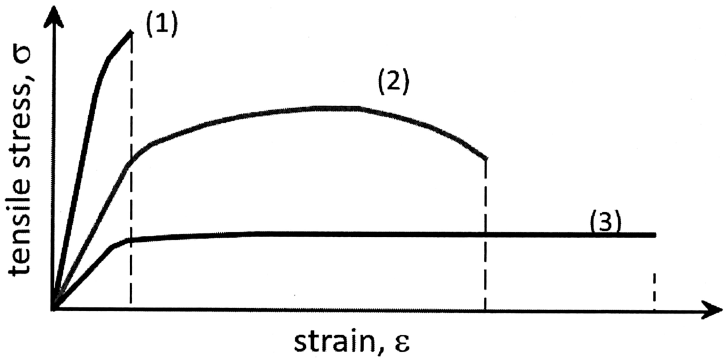


Figure 2

Solution:

Table 1

Property	**Rank**
Young's modulus	> >
Yield strength	> >
Tensile strength	> >
Ductility	> >
Toughness	> >

(b) Explain the following statement in your own words regarding the strength of a metal. "A perfect material, namely a perfectly pure crystal without defects in structure is perfectly useless."

(5 Marks)

Solution:

Note: Question 3 continues on page 7.

(c) Using Figure 3 and Hall-Patch Relation, estimate the yield strength of the material if it is nanostructured with a grain size of 50 nm.

(5 Marks)

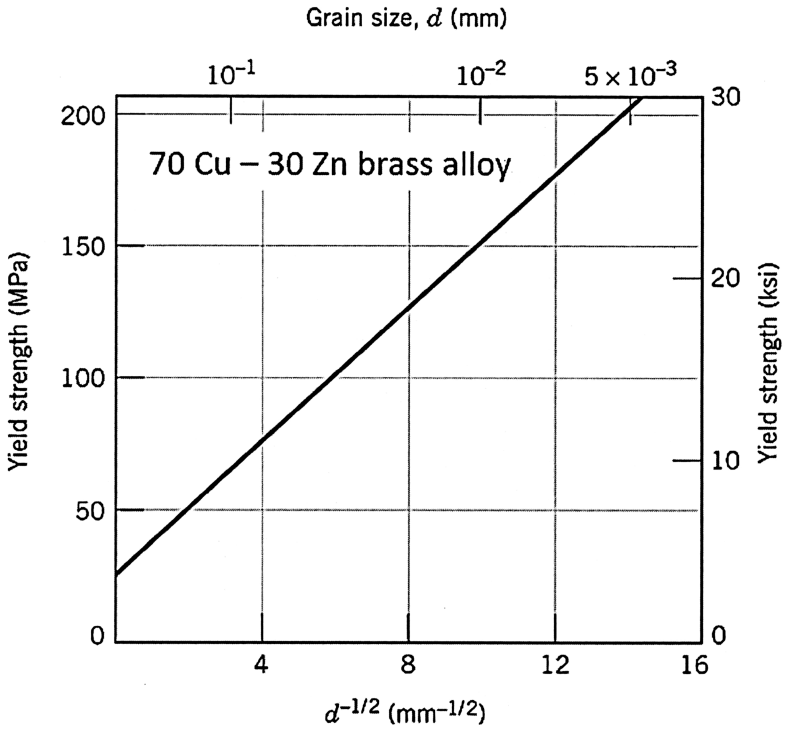


Figure 3

Solution:

Q4. (16 marks)

/16

This question relates to metal casting.

(a) A rectangular piece of dimensions 30×50×20 cm^3 is fabricated using sand casting and has a solidification time of 20 min. We add a cylindrical riser of diameter 5 cm and length 8 cm for this rectangular piece. What is the total solidification time of the riser?

The total solidification time T is given by the Chvorinov's rule: $T = C_m \left(\frac{V}{A}\right)^2$, where C_m is the mold constant, and V and A the volume and area of the cast, respectively.

(3 marks)

Solution:

(b) Is this a suitable riser? Justify your answer.

(1 mark)

Solution:

(c) We now want to modify the riser's geometry so that its solidification time is of 30 min. We decide to keep a cylindrical riser of length at 8 cm but to vary its diameter. What should be the new riser diameter to have a solidification time of 30 min?

(2 marks)

Solution:

Note: Question 4 continues on page 9.

(d) Is this a suitable riser? Justify your answer.

(1 mark)

Solution:

(e) Finally, we decide to make a riser with a ratio D/L = 1. What would in this case be the dimensions of the riser to have a solidification time of 30 min?

(2 marks)

Solution:

(f) If the dimensions of the cast part were $30\times50\times20$ mm^3 instead of $30\times50\times20$ cm^3 but with the same casting time, what would be the dimensions of the riser with a ratio D/L = 1?

(2 marks)

Solution:

(g) Would sand casting be a suitable method for fabricating this piece of dimensions $30\times50\times20$ mm^3? What other method can you propose and explain why.

(2 marks)

Solution:

Note: Question 4 continues on page 10.

(h) After sand casting, the piece has a rough surface. Using a stylus apparatus, the vertical deviations are measured and reported in the below table 2. Based on this data, what is the surface roughness Ra of the piece?

(2 marks)

Table 2: Vertical deviations measured using the stylus apparatus

Measurement number	Vertical deviation in μm
1	+100
2	+50
3	-10
4	+3
5	-80
6	-65
7	+46
8	-82
9	+4
10	+6

Solution:

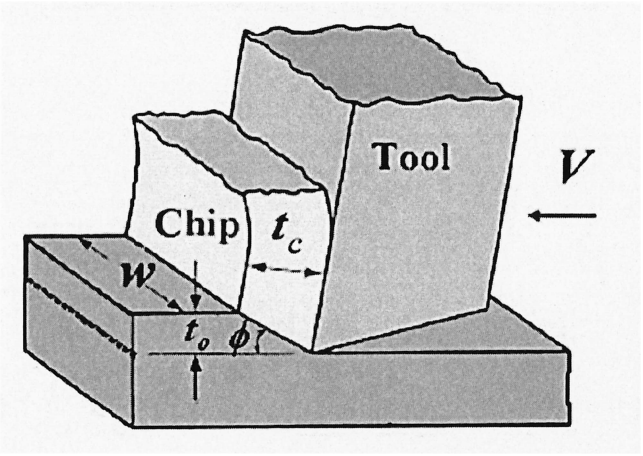
(i) Considering the other process you proposed in question (g), do you expect this other process to produce a piece with a higher or lower surface roughness? If you had proposed several methods, please select only one.

(1 mark)

Solution:

Q5. (18 marks) /18

Figure 4 shows a 2-D orthogonal cutting (OC) process with the various cutting parameters.



Cutting Parameters
w = 10mm
t_o = 2mm
t_c = 3mm
ϕ = 10°

Figure 4 A schematic diagram of an orthogonal cutting process

Determine the following:

(a) What is a relief angle? What function does it serve? What happens when the relief angle is not properly controlled?

(4 marks)

Solution:

(b) Cutting ratio

(2 marks)

Solution:

Note: Question 5 continues on page 12.

(c) Rake angle

(3 marks)

Solution:

(d) Given the chip velocity is 10 m/min, determine the material removal rate.

(5 marks)

Solution:

(e) Cutting power required for the OC process on all these materials listed in Table 3.

(4 marks)

Table 3 Specific energy requirements of various materials

Material	Specific Energy Requirements, J/mm^3
Aluminium alloys	0.7
High temperature alloys	5.9
Nickel alloys	5.5
Stainless steels	4.1

Solution:

Q6. (16 marks)

/16

(a) (i) Briefing discuss what is fusion and solid state welding in terms of the application of heat and pressure as well as filler.

(3 marks)

Solution:

(ii) Laser beam welding (LBW) and electron beam welding (EBW) are fusion welding processes having very high-power densities. Name two merits for the use of EBW over LBW.

(4 marks)

Solution:

(iii) A laser beam heat source is capable of transferring 3500J/sec to a metal part surface. 80% of the heat is concentrated in a circular area used to melt the metal. The minimum power density to melt the metal is given as $10W/mm^2$. What is the maximum diameter where melting of the metal can occur?

(3 marks)

Solution:

(b) A desired deep drawing process is to be performed on a blank sheet metal. The drawn part is a cylindrical cup of 50mm height with inside diameter of 70mm. Determine the required starting blank size D_b and thickness of the sheet metal, t.

(6 marks)

Solution:

END OF PAPER

MA2024 ENGINEERING MATERIALS & MANUFACTURING PROCESSES

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.