UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	:	**AAB1043 - METALS AND ALLOYS**
DATE	:	**9 AUGUST 2024 (FRIDAY)**
TIME	:	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SEVEN (7)** pages in this Question Booklet including the cover page .

ii. **DOUBLE-SIDED** Question Booklet.

1. Ferrous alloys are widely used in our everyday life. They can be classified as steels and cast iron.

   a. Sketch the microstructures of gray cast iron and white cast iron. Relate the microstructure of each cast iron to its mechanical properties.

   [12 marks]

   b. Discuss the influence and role of **TWO (2)** types of alloying elements on the properties of cast irons.

   [4 marks]

   c. Differentiate between steel alloys and cast iron in terms of their composition and heat treatment.

   [4 marks]

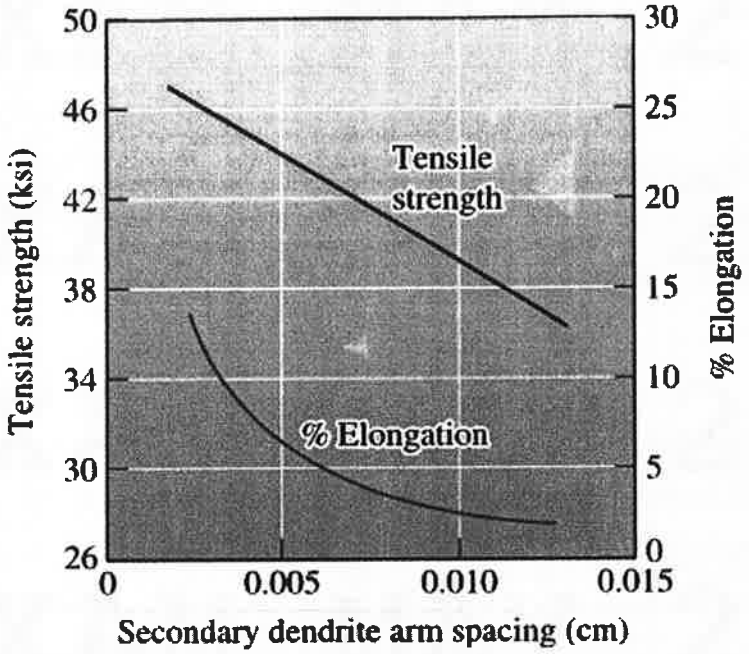
2. A manufacturing company is planning to produce aluminum alloy castings with dimensions of 30.5 cm (12 in) in length and 20.3 cm (8 in) in width. The castings are required to have a tensile strength of 289.0 MPa (42,000 psi). The company uses sand molds for casting, and the mold constant for aluminum alloys is determined to be 69928 min/m² (45 min/in²) and Chvorinov constant of 2. Given the Chvorinov's Rule: $t_s = B\left(\frac{V}{A}\right)^n$

a. Using the plots in **FIGURE Q2,** determine the minimum thickness (in cm) of the aluminum alloy casting required to meet the tensile strength requirement.

[16 marks]

b. Explain the significance of Chvorinov's rule in the context of casting design and solidification.

[4 marks]


50
46
42
38
34
30
26
Tensile strength (ksi)
30
25
20
15
10
5
0
% Elongation
Tensile strength
% Elongation
0
0.005
0.010
0.015
Secondary dendrite arm spacing (cm)

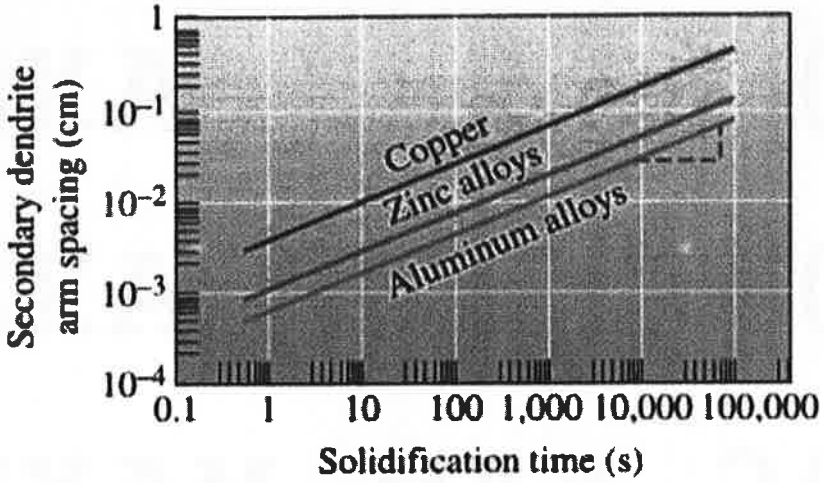

1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Secondary dendrite arm spacing (cm)
Copper
Zinc alloys
Aluminum alloys
0.1
1
10
100
1,000
10,000
100,000
Solidification time (s)

FIGURE Q2

3. A manufacturing company is considering two different designs for a cylindrical casting made from a pure metal. Design A has a diameter of 40 mm and a height of 80 mm, while Design B has a diameter of 80 mm and a height of 40 mm. The company aims to minimize solidification time to increase production efficiency.

Given the Chvorinov's Rule: $t_s = B\left(\frac{V}{A}\right)^n$

a. Calculate the solidification time for each design using Chvorinov's Rule with a Chvorinov constant of 2.0. Based on your calculations, determine which design would result in a shorter solidification time.

[12 marks]

b. With your proposed option of the cylinder size in **part (a)**, sketch the microstructure of the casting if the cooling takes place under equilibrium with no undercooling. Re-sketch the microstructure for an alloy instead of a pure metal. Name the growth and label accordingly.

[8 marks]

4. Consider the iron-carbon (Fe-C) equilibrium phase diagram shown in **FIGURE Q4** and answer the following questions.

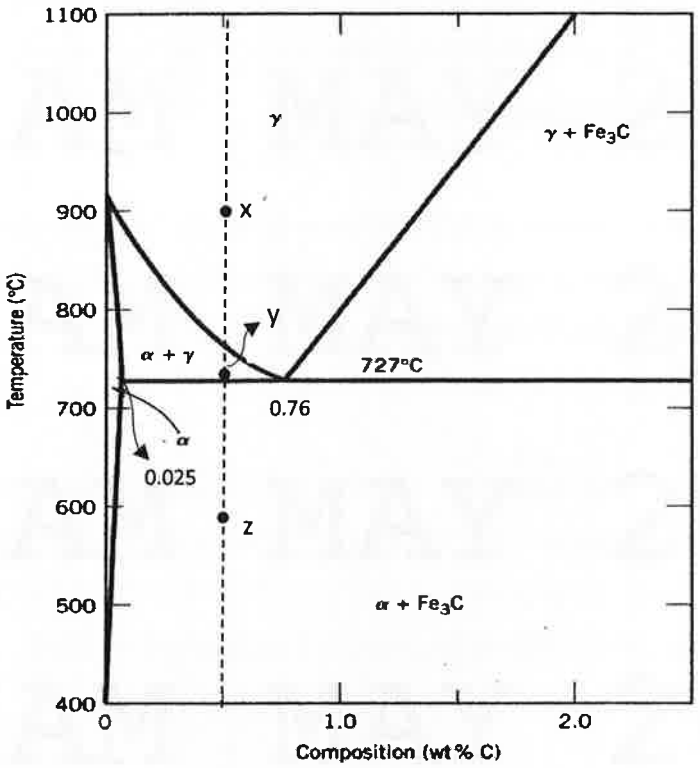


FIGURE Q4

a. Name the α and γ phases as indicated in **FIQURE Q4**.

[4 marks]

b. Consider a 0.40 weight percent carbon hypoeutectoid plain-carbon steel which is slowly cooled from 940°C to a temperature just slightly above 727°C. Determine the phases present, their compositions and amount.

[10 marks]

c. Sketch and describe the equilibrium microstructures that would be observed at points x, y and z in **FIGURE Q4** for an alloy of composition 0.50 percent carbon, as it is cooled from the γ phase region. Label the respective phase(s) formed.

[6 marks]

5. Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition in **FIGURE Q5**, specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 760°C and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

   i. Cool rapidly to 350°C, hold for 10^3 s, then quench to room temperature.

   ii. Rapidly cool to 625°C, hold for 10 s, then quench to room temperature.

   iii. Rapidly cool to 600°C, hold for 4 s, rapidly cool to 450°C, hold for 10 s, then quench to room temperature.

   iv. Rapidly cool to 300°C, hold for 20 s, then quench to room temperature in water. Reheat to 425°C for 10^3 s and slowly cool to room temperature.

   v. Rapidly cool to 575°C, hold for 20 s, rapidly cool to 350°C, hold for 100 s, then quench to room temperature.

   vi. Rapidly cool to 650°C, hold for 20 s, rapidly cool to 400°C, hold for 10^3 s, then quench to room temperature.

[20 marks]

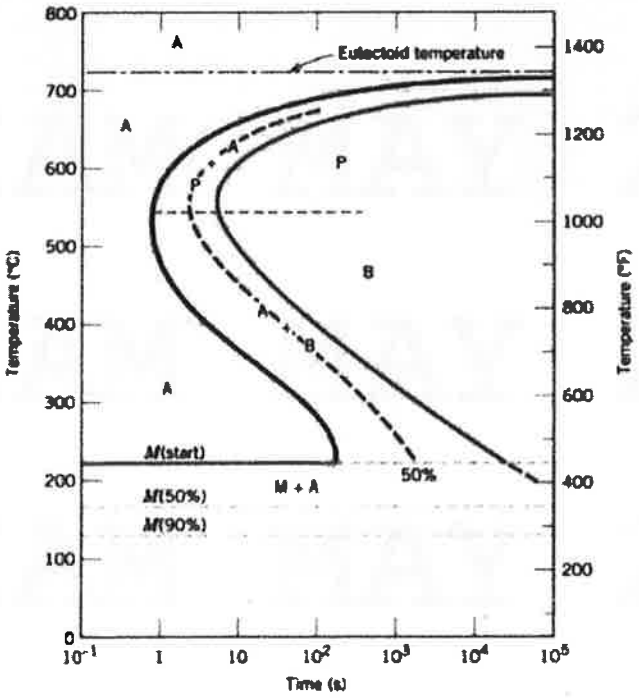


FIGURE Q5

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