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**CONFIDENTIAL**

**SET A**

# UNIVERSITI KUALA LUMPUR
## Malaysia France Institute

# FINAL EXAMINATION
# SEPTEMBER 2014 SESSION

| | | |
|---|---|---|
| **SUBJECT CODE** | : | **FTB11203** |
| **SUBJECT TITLE** | : | **MATERIAL SCIENCE** |
| **LEVEL** | : | **BACHELOR** |
| **DURATION** | : | **9.00 AM – 11.30 AM (2.5 HOURS)** |
| **DATE / TIME** | : | **8 JANUARY 2015** |

## INSTRUCTIONS TO CANDIDATES

1. **Please read the instructions given in the question paper CAREFULLY.**
2. **This question paper is printed on both sides of the paper.**
3. **Please write your answers on the answer booklet provided.**
4. **Answer should be written in blue or black ink except for sketching, graphic and illustration.**
5. **This question paper consists of TWO (2) sections only. Answer ALL questions in SECTION A and THREE (3) questions only in SECTION B.**
6. **Answer all questions in English.**

**THERE ARE 4 PRINTED PAGES OF QUESTIONS AND 3 PAGES OF APPENDICES EXCLUDING THIS PAGE.**

## SECTION A (Total: 40 marks)

**INSTRUCTION: Answer ALL questions. Please use answer booklet provided.**

**Question 1**

(a) Identify the type(s) of bonding would be expected for each of the following materials:

i. Brass (a copper-zinc alloy)

ii. Rubber

iii. Barium sulfide (BaS)

(6 Marks)

(b) Using the abbreviated quantum number notation (s, p, d, f), write the electronic configurations of the following ions:

(i) $Br^-$ (Atomic number for Bromine = 35)

(ii) $Ag^{2+}$ (Atomic number for silver = 47)

(iii) $Cu^{2+}$ (Atomic number for copper = 29)

(6 Marks)

(c) Composite is one of the engineering materials. Explain why the composite materials are important in engineering applications especially in aircraft manufacturing.

(8 Marks)

**Question 2**

(a) Calculate the radius of an iridium atom given that Ir has an FCC crystal structure, a density of 22.4 $g/cm^3$, and an atomic weight of 192.2 g/mol.

(9 marks)

(b) A plate of iron is exposed to a carburizing (carbon-rich) atmosphere on one side and a decarburizing (carbon-deficient) atmosphere on the other side at $700^oC$. If a condition of steady state is achieved, calculate the diffusion flux of carbon through the plate if the concentrations of carbon at positions of 5 and 10 mm beneath the carburizing surface are 1.2 and 0.8 $kg/m^3$, respectively. Assume a diffusion coefficient of C in Fe is $3 \times 10^{-11}$ $m^2/s$ at this temperature.

(6 marks)

(c) Describe the point defect that occurs in ceramic materials.

(5 marks)

## SECTION B (Total: 60 marks)

**INSTRUCTION: Answer THREE (3) questions only.**
**Please use answer booklet provided.**

### Question 1

A 1.5 kg specimen of a 95 wt% Cu – 5 wt% Ag alloy is heated to 850°C, at which temperature, it is entirely an α-phase solid solution (Figure 1). The alloy is to be melted to the extent that 50% of the specimen is liquid, the remainder being the α-phase. This may be accomplished either by heating the alloy or changing its composition while holding the temperature constant.

(a) Identify the lines labeled A, B and C.

(3 marks)

(b) Determine the temperature that specimen should be heated.

(7 marks)

(c) Calculate the amount of silver that must be added to the 1.5 kg specimen at 850°C to achieve this state (50%L+50%α).

(10 marks)

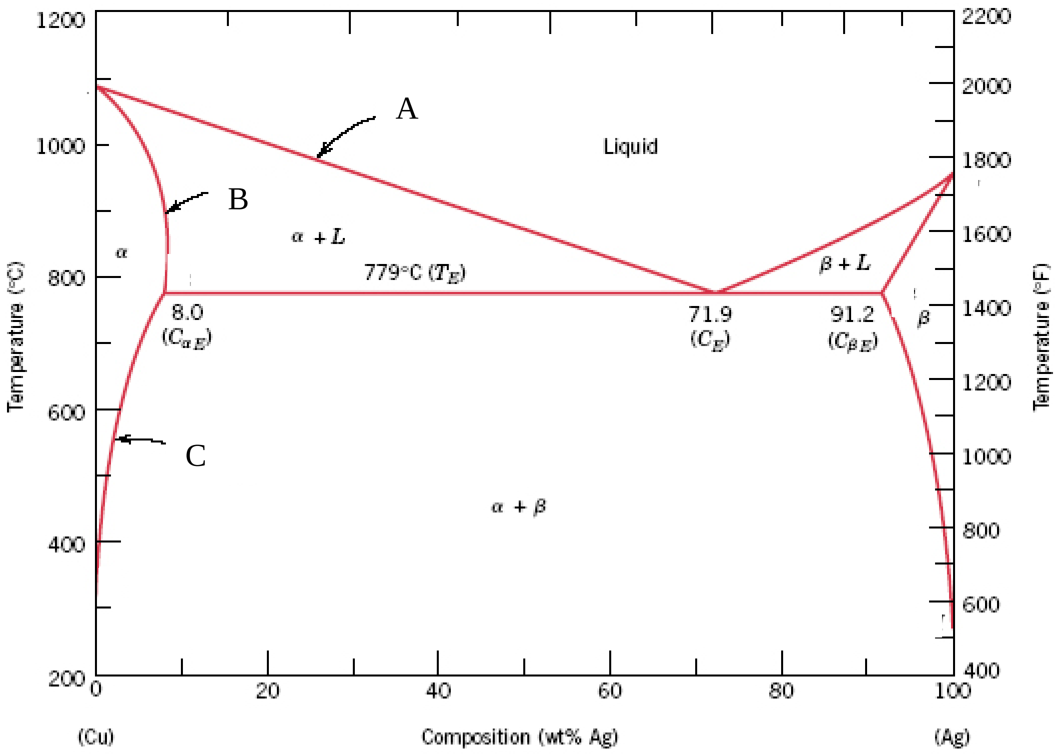


Figure 1: Copper – silver alloy phase diagram

**Question 2**

(a) Describe the pearlite and spheroidite microstructure.

(8 marks)

(b) Based on the time temperature transformation (TTT) diagram of eutectoid steel alloy given in Figure 2 (Appendix A), sketch and label on the diagram the time – temperature paths to produce the following microstructures:

(i) 100% coarse pearlite.

(4 marks)

(ii) 100% tempered martensite.

(4 marks)

(iii) 50% coarse pearlite, 25% bainite, and 25% martensite.

(4 marks)

**Question 3**

(a) Sketch a typical stress – strain curve for tensile testing result and label the important point below:

i) ultimate tensile strength

ii) breaking strength

iii) yield point

(8 Marks)

(b) A cylindrical rod 380 mm long, having a diameter of 10.0 mm, is to be subjected to a tensile load. If the rod is to experience neither plastic deformation nor an elongation of more than 0.9 mm when the applied load is 24,500 N, suggest which of the four metals or alloys listed in the Table 1 below are possible candidates? Justify your choice(s).

Table 1: Mechanical properties of materials

| Material | Modulus of Elasticity (GPa) | Yield Strength (MPa) | Tensile Strength (MPa) |
|---|---|---|---|
| Aluminum alloy | 70 | 255 | 420 |
| Brass alloy | 100 | 345 | 420 |
| Copper | 110 | 250 | 290 |
| Steel alloy | 207 | 450 | 550 |

(12 Marks)

**Question 4**

(a) The ends of a cylindrical rod 6.4 mm in diameter and 250 mm long are mounted between rigid supports. The rod is stress free at a temperature of 20$^o$C; and upon cooling to -40$^o$C, a maximum thermally induced tensile stress of 125MPa is possible. Suggest which of the following metals or alloys may the rod be fabricated: aluminum (E = 69 x $10^3$ MPa), copper (E = 110 x $10^3$ MPa), brass (E = 97 x $10^3$ MPa), 1025 steel (E = 207 x $10^3$ MPa), or tungsten (E = 407 x $10^3$ MPa)? Justify your answer.

(8 marks)

(b) Explain the material properties based on chart in the Figure 3.

(6 marks)

(c) Propose **TWO (2)** examples of application that require stiff materials and **ONE (1)** that require low density materials.

(6 marks)

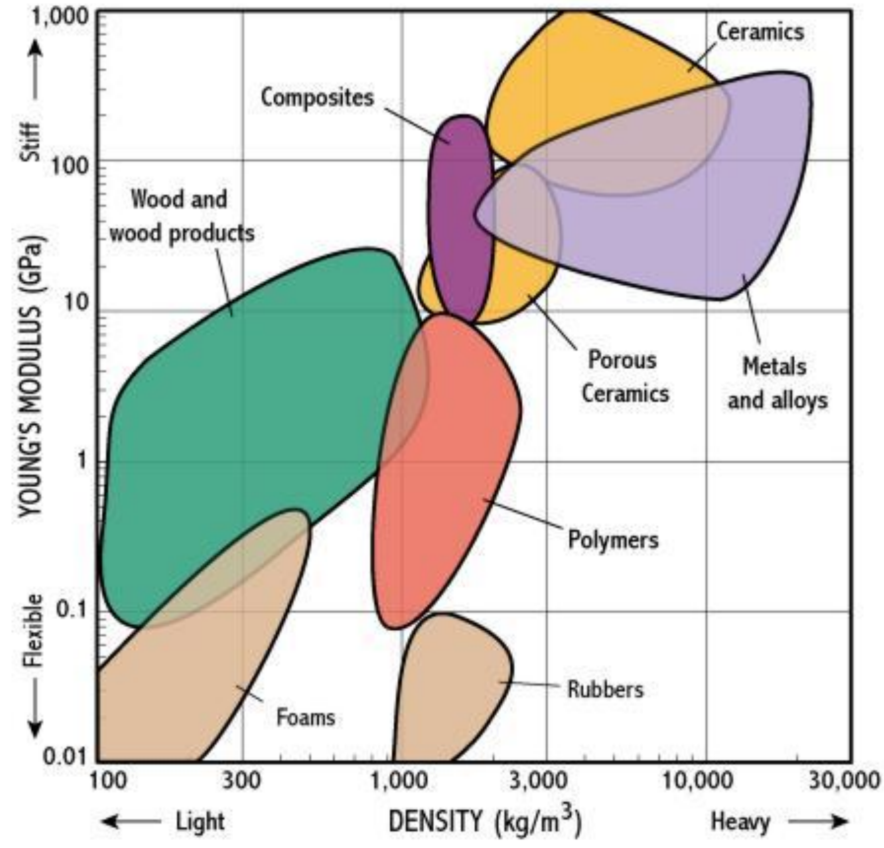


Figure 3: Material Properties Chart

**END OF QUESTION**

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**APPENDIX A**

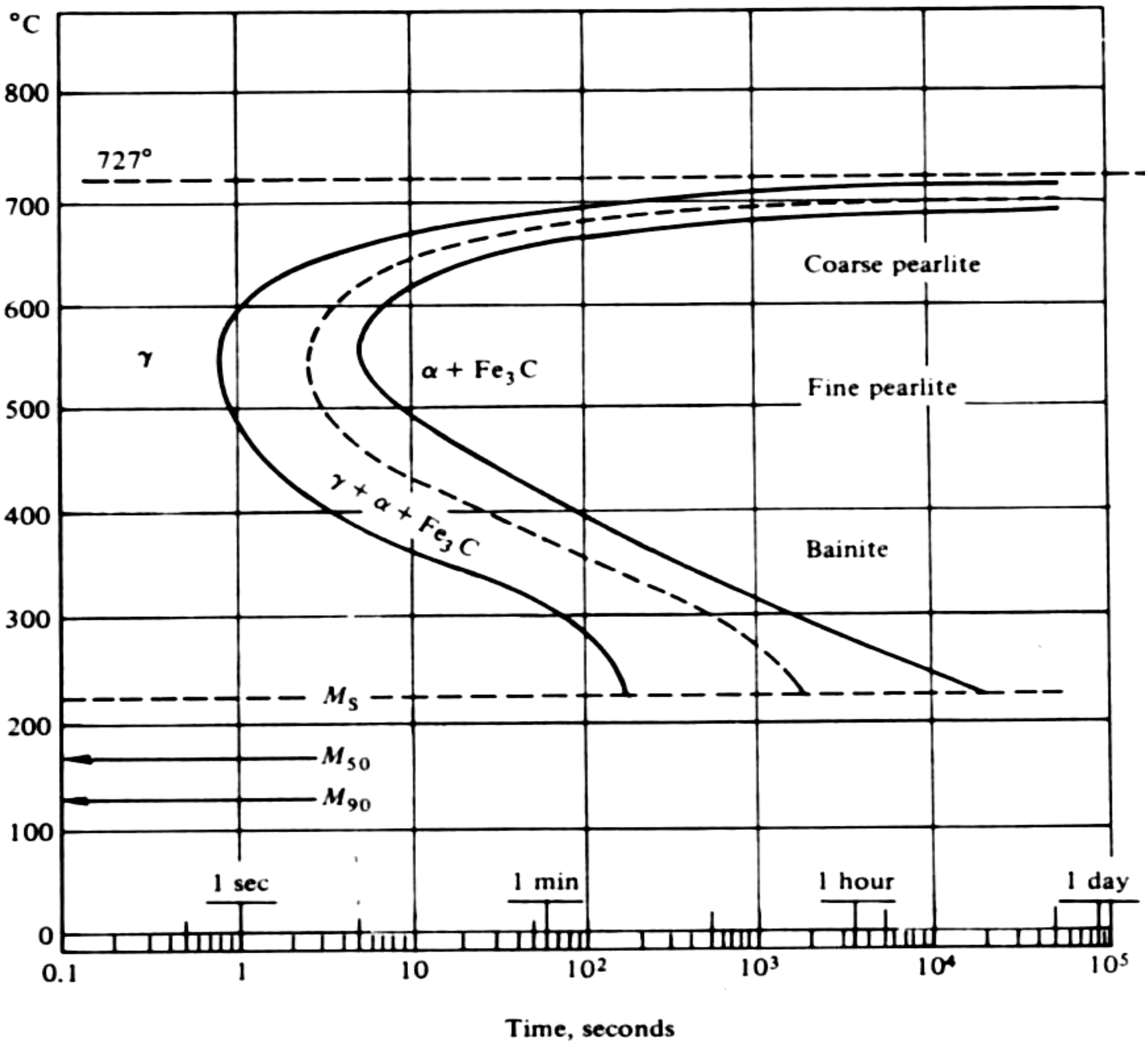


Figure 2: TTT diagram for eutectoid steel alloy

## APPENDIX B

## Tabulation of the Thermal Properties for a Variety of Materials

| Material | $C_p$ (J/kg.K) | $\alpha_l$ [$(^oC)^{-1}$ x $10^{-5}$] | k (W/m.K) | L [Ω.W/(K)$^2$ x $10^{-8}$] |
|---|---|---|---|---|
| **Metals** | | | | |
| Aluminum | 900 | 23.6 | 247 | 2.20 |
| Copper | 386 | 17.0 | 398 | 2.25 |
| Gold | 128 | 14.2 | 315 | 2.50 |
| Iron | 448 | 11.8 | 80 | 2.71 |
| Nickel | 443 | 13.3 | 90 | 2.08 |
| Silver | 235 | 19.7 | 428 | 2.13 |
| Tungsten | 138 | 4.5 | 178 | 3.20 |
| 1025 Steel | 486 | 12.0 | 51.9 | - |
| 316 Stainless Steel | 502 | 16.0 | 15.9 | - |
| Brass (70Cu-30Zn) | 375 | 20.0 | 120 | - |
| Kovar (54Fe-29Ni-17Co) | 460 | 5.1 | 17 | 2.80 |
| Invar (64Fe-36Ni) | 500 | 1.6 | 10 | 2.75 |
| Super Invar (63Fe-32Ni-5Co) | 500 | 0.72 | 10 | 2.68 |
| **Ceramics** | | | | |
| Alumina ($Al_2O_3$) | 775 | 7.6 | 39 | - |
| Magnesia (MgO) | 940 | 13.5 | 37.7 | - |
| Spinel ($MgAl_2O_4$) | 790 | 7.6 | 15.0 | - |
| Fused Silica ($SiO_2$) | 740 | 0.4 | 1.4 | - |
| Soda-lime Glass | 840 | 9.0 | 1.7 | - |
| Borosilicate (Pyrex) glass | 850 | 3.3 | 1.4 | - |
| **Polymers** | | | | |
| Polyethylene high density (HDPE) | 1850 | 106-198 | 0.46-0.50 | - |
| Polypropylene | 1925 | 145-180 | 0.12 | - |
| Polystyrene | 1170 | 90-150 | 0.13 | - |
| Polytetrafluoroethylene (Teflon) | 1050 | 126-216 | 0.25 | - |
| Phenol-formaldehyde, phenolic (Bakelite) | 1590-1760 | 122 | 0.15 | - |
| Nylon 6,6 | 1670 | 144 | 0.24 | - |
| Polyisoprene | - | 220 | 0.14 | - |

# FORMULAE

$$APF = (n)(\frac{4\pi r^3}{3})(\frac{1}{a^3})$$

$$\rho = \frac{nA}{V_c N_A}$$

$$N = \frac{N_A \rho}{A}$$

$$N_v = Ne^{(\frac{-Q}{kT})}$$

$$a_{fcc} = \frac{4r}{\sqrt{2}}$$

$$a_{bcc} = \frac{4r}{\sqrt{3}}$$

$$a_{sc} = 2r$$

$$D = D_o e^{(\frac{-Q_d}{RT})}$$

$$m_\alpha\, phase = \frac{m_L - m_x}{m_L - m_\alpha}\, x Total\ Mass$$

$$m_L\, phase = \frac{m_x - m_\alpha}{m_L - m_\alpha}\, x Total\ Mass$$

$$m_L\, phase\% = \frac{m_s\% - m_x\%}{m_s\% - m_{L\%}}\, x100$$

$$m_s\, phase\% = \frac{m_x\% - m_L\%}{m_s\% - m_{L\%}}\, x100$$

$$\rho_\alpha = \frac{100}{\frac{C_{A(\alpha)}}{\rho_A} + \frac{C_{B(\alpha)}}{\rho_B}}$$

$$\rho_\beta = \frac{100}{\frac{C_{A(\beta)}}{\rho_A} + \frac{C_{B(\beta)}}{\rho_B}}$$

$$\Delta L = L_o \alpha_1 \Delta T$$

$$\Delta V = 3\alpha_1 V_o \Delta T$$

$$\sigma = E\alpha_l \Delta T$$

$$V_\alpha = \frac{\frac{m_\alpha}{\rho_\alpha}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}$$

$$V_\beta = \frac{\frac{m_\beta}{\rho_\beta}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}$$

$$\sigma = \frac{F}{A_o}$$

$$\varepsilon = \frac{\Delta l}{l_o}$$

$$E = \frac{\sigma}{\varepsilon}$$

$$\%elongation = \frac{\Delta l}{l_o}\, x100\%$$

$$\%\ area\ reduction = \frac{\Delta A}{A_o}\, x100\%$$

$$BHN = \frac{F}{\frac{\pi D}{2}(D - \sqrt{D^2 - d^2})}$$

$$VHN = \frac{1.85F}{d^2}$$

$$Q = \mathrm{mC}\theta$$

$$C = \frac{dQ}{dT}$$

$$q = -k\frac{dT}{dx}$$

$$Q = q\mathrm{At}$$