**Birla Institute of Technology and Science, Pilani**
**Second Semester, 2017-18**
**CHE F243-Materials Science and Engineering**

**Comprehensive Examination** **9th May, 2018 (8-11 am)**
**Max Time: 180 min** **Total Max Marks:105**
**Name:** **ID:**

This question paper is divided into two sections; A & B. SECTION A -Closed Book (tentatively for 95 min) and SECTION B-Open Book. Answer Section A first in the provided answer sheet and return it to get Section B. No time bound is imposed.
**Negative marking of the same weightage is imposed on Q1 and Q2 of section A only.**

## SECTION A (Closed Book-55 Marks)

**Q1: Multiple choice: cross the right one only. Multiple crosses automatically make the answer incorrect [1x20]**

**A.** The degree of anisotropic effects in the crystal structure could follow the order
a. Cubic>Tetragonal>Orthorhombic> Triclinic
b. Triclinic>Cubic> Orthorhombic>Tetragonal
c. Cubic>Tetragonal> Triclinic >Orthorhombic
d. Tetragonal>Orthorhombic>Cubic> Triclinic
e. Triclinic>Orthorhombic>Tetragonal>Cubic

**B.** Maximum diffusivity of CO is expected to occur in a polypropylene with
**a.** 15 % crystallinity
**b.** 25 % crystallinity
**c.** 40 % crystallinity
**d.** 50 % crystallinity
**e.** 60 % crystallinity

**C.** For the same diffusion time, the depths of diffusion penetration at 500 and 850 ºC is in the ration of 1:6. The activation energy for diffusion is
**a.** 174 kJ/mol
**b.** 47 kJ/mol
**c.** 74 kJ/mol
**d.** 37 kJ/mol
**e.** 148 kJ/mol

**D.** For an ideal case, the closest fraction of voids filled by the trivalent ions in an inverse spinel structure is:
**a.** 0.25
**b.** 0.50
**c.** 0.75
**d.** 0.38
**e.** 0.68

**E.** The migration of atoms in a pure material is called
**a.** Interstitial diffusion
**b.** Self-diffusion
**c.** Mixed diffusion
**d.** None of the above
**e.** Substitutional diffusion

**F.** X-Ray diffraction study cannot be used to find
**a.** Elemental composition
**b.** Phase composition
**c.** Crystallite size
**d.** Crystal strain
**e.** Lattice parameters

**G.** Which of the following statements is true for binary iron–iron carbide system?
**a.** Ni addition increase eutectoid C wt% and temperature.
**b.** Mo addition decrease eutectoid C wt% and temperature

**c.** Ti addition decrease eutectoid C wt% and temperature
**d.** Si addition decrease eutectoid C wt% and temperature
**e.** Ni addition decrease eutectoid C wt% and temperature

**H.** Which of the following statements is true?
**a.** Burger vector motion is parallel to direction of motion of dislocation line for edge dislocation
**b.** Burger vector motion is perpendicular to direction of dislocation line for edge dislocation
**c.** Burger vector motion is parallel to direction of motion of dislocation line for screw dislocation
**d.** Burger vector motion is perpendicular to applied stress for screw dislocation
**e.** Burger vector motion is perpendicular to applied stress for edge dislocation

**I.** Which of the following directions cannot be possible for a Hexagonal Bravais lattice?
**a.** $[11\bar{2}0]$
**b.** $[1\bar{1}00]$
**c.** $[11\bar{0}3]$
**d.** $[1\bar{1}01]$
**e.** $[2\bar{1}\bar{1}0]$

**J.** When light is transmitted from air (refraction index = 1) into a diamond (refraction index =2.41) interface at normal to the interface, then % of light reflected from diamond will be
**a.** ~ 17
**b.** ~71
**c.** ~35
**d.** ~1.7
**e.** ~41

**K.** The term 'Magnetostriction' in a material can be associated with the
**a.** Magnetically induced irreversible elastic strain
**b.** Magnetically induced irreversible plastic strain
**c.** Magnetically induced reversible plastic strain
**d.** Magnetically induced reversible elastic strain
**e.** Magnetically induced irreversible total strain

**L.** At room temperature the magnetic easy axis for Fe and Ni are
**a.** [110] and [111], respectively.
**b.** [100] and [110], respectively.
**c.** [110] and [100], respectively.
**d.** [111] and [100], respectively.
**e.** [100] and [111], respectively.

**M.** Consider that CaO has NaCl structure with lattice parameter 0.481 nm and diffusion constant of $Ca^{2+}$ ion at 2000 K is ~$10^{-14}$ $m^2/s$. The ionic conductivity (S/cm) results by $Ca^{2+}$ diffusion in CaO at 2000 K is:
**a.** ~ 3.1 x $10^{-5}$
**b.** ~ 1.3 x $10^{-5}$
**c.** ~3.25 x $10^{-6}$
**d.** ~3.25 x $10^{-5}$
**e.** ~1.3 x $10^{-6}$

**N.** Usually mechanical strength of a polymer compound follows the steriochemical configuration order (considering all other factors are same)
**a.** Isotactic>Syndiotactic>Atactic
**b.** Syndiotactic>Atactic> Isotactic
**c.** Syndiotactic=Atactic> Isotactic
**d.** Atactic> Isotactic> Syndiotactic>
**e.** Isotactic<Syndiotactic<Atactic

**O.** For thermoplastics decrease in testing temperature
**a.** Increases elastics modulus and decrease tensile strength & elongation

**b.** Decreases elastics modulus & elongation and increase tensile strength.
**c.** Increases elastics modulus, tensile strength, and elongation
**d.** Increases elastics modulus & tensile strength and decrease elongation
**e.** Decreases elastics modulus & tensile strength, and increase elongation

**P.** If 45 grains per square inch are measured for a metal specimen at a magnification of 85X, the ASTM grain size number in terms of the closest integer will be
**a.** 7
**b.** 6
**c.** 8
**d.** 9
**e.** 5

**Q.** For optical microscope resolution improves (smaller $d_{min}$) if
**a.** Wave length of light decreases and/or n-imaging medium refractive index increases and/or objective angular aperture decreases
**b.** Wave length of light increases and/or n-imaging medium refractive index increases and/or objective angular aperture decreases
**c.** Wave length of light probe decreases and/or imaging medium refractive index increases and/or objective angular aperture increases
**d.** Wave length of light decreases and/or n-imaging medium refractive index increases and/or eye piece angular aperture increases
**e.** Wave length of light decreases and/or n-imaging medium refractive index increases and/or eye piece angular aperture decreases.

**R.** Usually the order of Magnetic susceptibility in different magnetic materials is:
**a.** Diamagnetic<vacuum<paramagnetic< ferromagnetic<ferromagnetic
**b.** Diamagnetic>vacuum>paramagnetic>ferromagnetic>ferromagnetic
**c.** Diamagnetic>paramagnetic >vacuum >ferromagnetic>ferromagnetic
**d.** Diamagnetic>vacuum>paramagnetic=ferromagnetic>ferromagnetic
**e.** Diamagnetic>vacuum<paramagnetic>ferromagnetic>ferromagnetic

**S.** For the case of γ- Fe transforming to martensite ($\alpha'$), according to the Bain model which of the following changes is true?
**a.** $(111)_\gamma \rightarrow (111)_{\alpha'}$
**b.** $[101]_\gamma \rightarrow [011]_{\alpha'}$
**c.** $[110]_\gamma \rightarrow [011]_{\alpha'}$
**d.** $(111)_\gamma \rightarrow (011)_{\alpha'}$
**e.** $[112]_\gamma \rightarrow [001]_{\alpha'}$

**T.** At a peritectoid reaction (between two components) system degree of freedom is
**a.** 0
**b.** 1
**c.** 2
**d.** 3
**e.** 4

**Q 2: Fill in the blanks with the right technical word(s) only. Both word(s) must be correct in order to consider the question right. [1 x 20]**

**A.** Gallium phosphide (GaP) having a band gap of 2.26 eV, is transparent & colorless to the radiations having wavelengths _____ than _____ μm.

**B.** The critical _____ angle ($\phi_c$) for light passing from diamond (refraction index =2.41) into air (refraction index = 1) is _____.

**C.** For each electron in an atom the exact relation of spin _____ moment ($\mu_B$) with electron charge (e), Plank's constant (h), and electron mass (m) can be expressed by the equation _____.

**D.** In terms of hysteresis behavior, a hard magnetic material has a _____ coercivity and _____ energy losses.

**E.** Velocity of _____ in calcium fluoride ($CaF_2$), which has a dielectric constant ($\varepsilon_r$) of 2.056 (at frequencies within the visible range) and a magnetic susceptibility of $-1.43 \times 10^{-5}$ is _____.

**F.** In case of creating atomic bonding the equilibrium spacing ($r_0$) between two isolated atoms occurs when _____ + repulsive force _____ 0.

**G.** If _____ of two elements A and B are 3.1 and 1.7, respectively, then the percentage ionic character of a bond between elements A and B can be calculated as _____.

**H.** Although, more than one single unit cell may be chosen for a particular crystal structure; however, we generally use the unit cell having the _____ level of _____ symmetry.

**I.** For metallic deformation, slip occurs on the _____ densely packed crystallographic planes and, in those planes, along directions having the _____ atomic packing.

**J.** For microscopic techniques, depth of field _____ as the magnification _____.

**K.** The thermal shock resistance is best for ceramics that have _____ thermal conductivities, and low coefficients of _____.

**L.** Susceptibility and coercivity depends more on structural _____, although, saturation magnetization is determined only by the _____ of the material.

**M.** Considering the annealing of a heavily cold worked copper sample, recrystallization stage influences the tensile strength and brittleness _____ than that in the grain _____ stage.

**N.** Two essential primary conditions for a polymer to become conductive are proper _____ and presence of _____ double bonds.

**O.** According to the SAE designation the carbon steels are designated by a _____ number, where _____ digits indicate the amount of carbon.

**P.** For a metal-oxide-semiconductor field-effect-transistor (MOSFET), the central to the functionality is the gate _____, which attracts charge carriers into the _____ region.

**Q.** The full form of the optical devise LASER is Light Amplification by _____ Emission of _____.

**R.** Diffusion by _____ mechanism is usually faster than that by _____ mechanism.

**S.** The time dependent change in stress with respect to maintained constant strain is known as _____ _____.

**T.** Regarding substitutional solid solutions, one of the Hume-Rothery rules says the _____ radius of the solute and solvent atoms must not differ more than _____.

**Q3: Conceptual/Short Questions. Answer to the point & with logic [3 x 5]**

**a)** Could this following equation be considered to be true for nucleation phenomena connected with liquid to solid transformation? Why? Or why not? Provide explanation with proper equations only

$$0 \leq \Delta G^{*}_{het} \leq \Delta G^{*}_{\mathrm{hom}o}$$

**b)** Consider that you are substituting 0.01 mole % of $ZrO_2$ by CaO. Write the appropriate defect reaction for the substitution of $ZrO_2$ by CaO using the Kroger-Vink notation. What will happen to the conductivity of $ZrO_2$? Increase or decrease? Why? Explain with proper logic.

**c)** Explain the working principle for a p-n junction solar cell within 3-4 lines with proper schematic(s).

**d)** Show the trend of thermal conductivity vs temperature for pure MgO and $Al_2O_3$. Explain the graphs.

**e)** At room temperature the microstructures of eutectic & eutectoid Fe-C alloys are different. Draw and label these microstructures to show the differences and explain why these differences occur.

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Avoid penalization by

- Answering the questions consecutively.
- Not skipping any mathematical steps
- Striking out all rough works clearly you don't want to be considered.
- Boxing the final and intermediate answers with unit
- Not writing vague and irrelevant language

## SECTION B (Open Book-50 Marks)

**Q1:** Follow the mentioned notations ($C_{(111)}$, etc.) for calculations and showing results

a) Calculate the planar density for cation ($C_{(111)}$) and anion ($A_{(110)}$) in ions per square nanometer on the (111) and (110) planes, respectively for LiF with proper explanation necessary. **[3x2]**

b) Calculate linear density for cation ($C_{[110]}$) and anion ($A_{[111]}$) in ions per nanometer on [110] and [111] directions, respectively for LiF with proper explanation necessary. **[2x2]**

**Q2:** The two ends of a cylindrical aluminum rod 75.00 mm long and 10.000 mm in diameter are maintained rigid to fix dimension along length only. If the rod is initially at 25°C, to what temperature ($T_f$) must it be cooled to have a 0.008 mm reduction in diameter? Solve according to the following steps.

a) **Step1:** Explain your procedure or approach according to the problem given. Mention the data (refer table, page etc.) you have to use from your class text book. **[4]**

b) **Step 2:** Derive the final equation showing relation between $T_f$ and other variables based on your approach in step 1. **[3+2]**

c) **Step 3:** Calculate the final result. **[1]**

Mixing steps are not accepted.

**Q3:** A 90 wt% Cu–10 wt% Ni alloy is known to have an electrical resistivity of $2.3 \times 10^{-7}$ Ω-m at room temperature (25 ºC). Calculate the composition (in wt%) of a copper– nickel alloy that gives a room-temperature resistivity of $2.7 \times 10^{-7}$ Ω-m. Assume that copper and nickel form a solid solution. Solve according to the following steps.

a) **Step 1:** Explain your procedure for approach according to the problem given. Mention the data (refer table, page etc.) you have to use from your class text book. **[3]**

b) **Step 2:** Solve stepwise based on your approach. **[7]**

Mixing steps are not accepted.

**Q4:** The transmissivity ***T*** of a transparent material 10 mm thick to normally incident light is 0.80. If the index of refraction of this material is 1.5, compute the thickness of material that will yield a transmissivity of 0.70. All reflection losses should be considered. Solve according to the following steps.

a) **Step 1:** Explain your procedure or approach according to the problem given. Mention the data (refer table, page etc.) you have to use from your class text book **[5]**

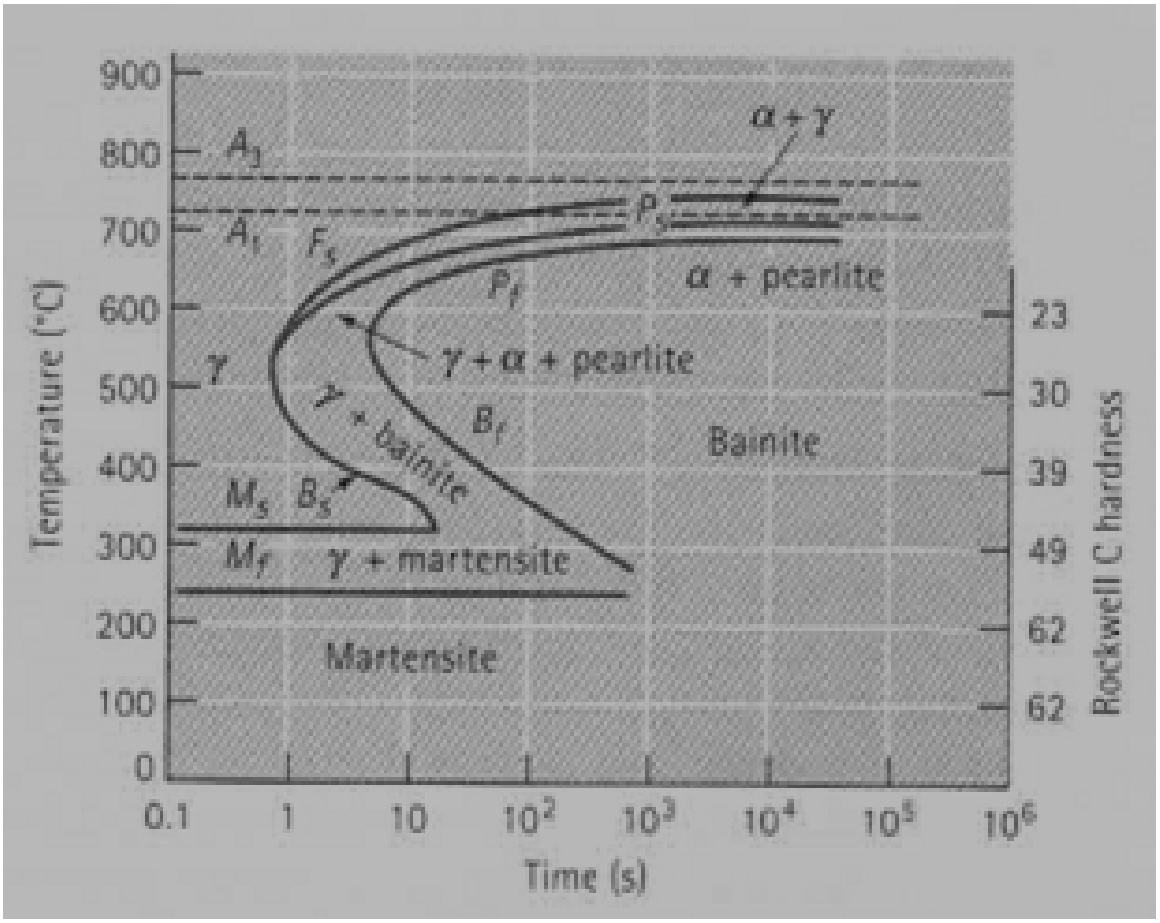
b) **Step 2:** Solve stepwise based on your approach in step 1. **[5]**

Mixing steps are not accepted.

**Q5:** Determine (in terms of the tentative % of the micro-constituents present), sketch, & label the final microstructure of a small 1050 steel specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen has been heated at 920 ºC, and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure. Utilize the TTT diagram shown in next page

a) Rapidly cool to 700 ºC, hold at this temperature for 110 s, then quench to room temperature.

b) Rapidly cool to 650 ºC, hold at this temperature for 5 s, rapidly cool to 400 ºC, hold for 25 s, then quench to room temperature.
c) Rapidly cool to 350 ºC, hold for 2 s, then quench to room temperature.
d) Rapidly cool to 675 ºC, hold for 30 s, then quench to room temperature. Then heat it to 700 ºC and hold for 20 hr.
e) Rapidly cool to 600 ºC, hold at this temperature for 100 s, rapidly cool to 450 ºC, hold at this temperature for 4 s, then quench to room temperature. **[2 x 5]**

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