Birla Institute of Technology and Science, Pilani
Second Semester, 2016-17
CHE F243-Materials Science and Engineering

Comprehensive Examination **13th May, 2017 (8-11 am)**
Max Time: 180 min **Total Max Marks:105**

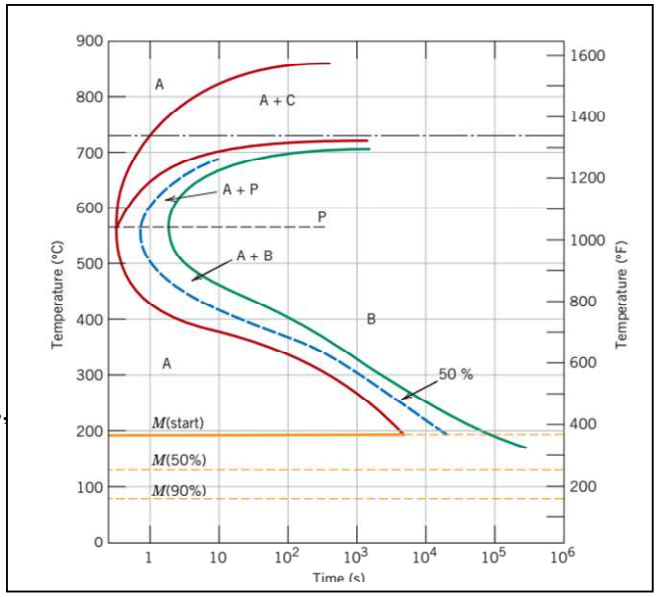
This question paper is divided into two sections; A & B. SECTION A -Closed Book (tentatively for 95 min) and SECTION B-Open Book. Answer Section A first in the provided answer sheet and return it to get Section B. No time bound is imposed.

- Please answer the questions consecutively in each section.
- Don't skip any mathematical steps-otherwise you will lose marks
- Clearly strike out all rough works you don't want to be considered.
- Box the final and intermediate answers
- Irrelevant writing will be penalized

SECTION A (Closed book-55 Marks)

Q1: **[(1+1)x 8]**

Draw the following TTT diagram for a 1.13 wt% C steel alloy as per scale (A→ austenite; B → bainite; C → proeutectoid cementite; M → martensite; P → pearlite). Determine (show the path), draw, and clearly label the final microstructure of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 920 °C (1690 ° F) and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.



a) Quench to 350 °C (660 ° F) , hold for 300 s, then quench to room temperature.

b) Quench to 675 °C (1250 ° F) , hold for 7 s, then quench to room temperature.

c) Quench to 600 °C (1110° F) , hold at this temperature for 7 s, quench to 450 °C (840 ° F), hold at this temperature for 4 s, then quench to room temperature.

d) Quench to 250 °C (480 ° F) , hold for 10^3 s, then quench to room temperature.

e) Quench to 775 °C (1430 ° F) , hold for 500 s, then quench to room temperature.

f) Quench to 400 °C (750 ° F) , hold for 500 s, then quench to room temperature.

g) Quench to 700 °C (1290 ° F) , hold at this temperature for 10^5 s, then quench to room temperature.

h) Quench to 650 °C (1200 ° F) , hold at this temperature for 3 s, quench to 400 °C (750 ° F), hold for 25 s, then quench to room temperature.

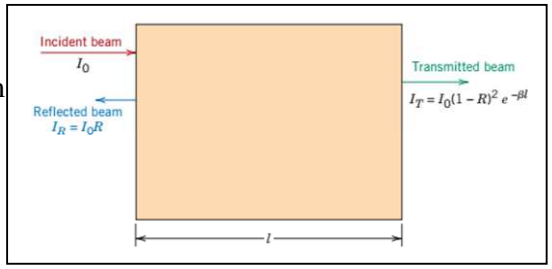
Q2: If a cylindrical rod of nickel 100.00 mm long and 8.000 mm in diameter is heated from 20°C to 200°C while its ends are maintained rigid, determine its change in diameter. Explain your process and steps clearly. No explanation no marks. E = 207 GPa, $\alpha_l = 13.30 \times 10\text{-}6\ (°C)^{-1}$, Poisson's ratio for Ni is 0.31, heat capacity for Ni is 443 J/kg-K, thermal conductivity 90 W/m-K. **[8]**

Q3: Calculate (mathematically, not graphically) the electrical resistivity of copper containing 1.75 at% Ni at 100°C. Explain your process, and show all intermediate steps & calculations clearly. No explanation no marks. **[10]**

Q4: The indices of refraction of fused silica and a soda–lime glass within the visible spectrum are 1.458 and 1.51, respectively. For each of these materials determine the fraction of the relative dielectric constant at

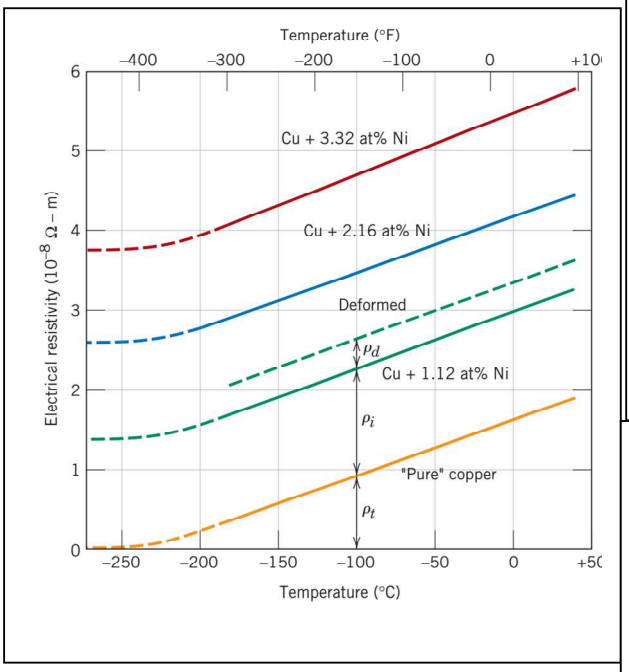
60 Hz that is due to electronic polarization. Neglect any orientation polarization effects. The ε_r for fused silica and soda-lime glass are 4.0 and 6.9, respectively, at 60 Hz. Explain your process, and show all intermediate steps & calculations clearly. No explanation no marks. **[6]**

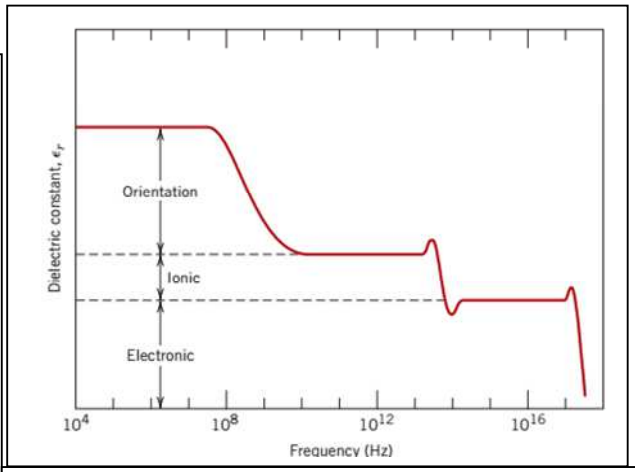
Q5: Consider the phenomena of absorption, reflection, and transmission all applied to the passage of light through a transparent solid show in the figure. For an incident beam of intensity I_0 that impinges on the front surface of a specimen of thickness l and absorption coefficient β, prove mathematically that the transmitted intensity at the back face is $I_T = I_0(1-R)^2 e^{-\beta l}$ **[7]**

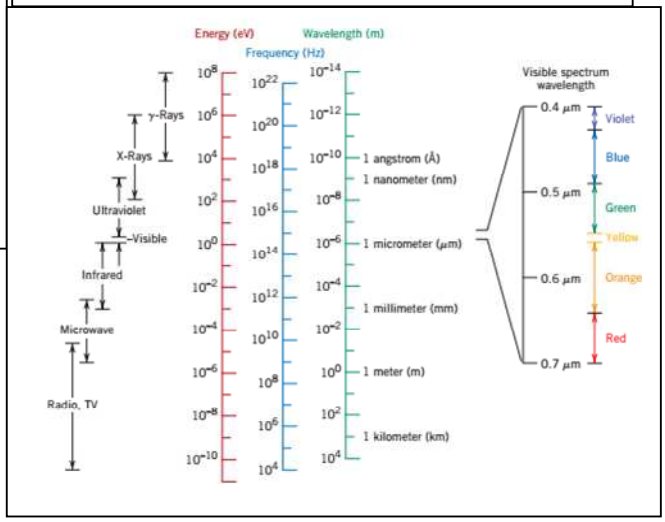


Q6: Design all possible and really available cubic mixed-ferrite magnetic material that has a saturation magnetization of 4.6×10^5 A/m. Assuming that the unit cell edge length (0.839 nm) remains same after doping also. For Cr, Mn, Fe, Co, Ni, and Cu atomic number starts from 24 and increased consecutively to 29. Explain your process, and show all intermediate steps & calculations clearly. No explanation no marks. **[8]**

General data you may need to use







Bonus Questions (All questions must be answered before starting bonus questions)

A certain rare-earth magnet has a magnetization-demagnetization curve that can be expressed as $B = 5e\text{-}7H^2 + 3.4e\text{-}5H - 2$, where B is in T and H is in kA/m.

a) Calculate H_c **[4]**

b) Calculate $(BH)_{max}$? **[6]**

Birla Institute of Technology and Science, Pilani
Second Semester, 2016-17
CHE F243-Materials Science and Engineering

Comprehensive Examination **13th May, 2017 (8-11 am)**
Max Time: 180 min **Total Max Marks:105**

This question paper is divided into two sections; A & B. For the section A, use the question paper. Write answers of section B on the answer sheet. There is not time bound. Return Section A and B together, Don't tie.

SECTION B (Open book-50 Marks)

Q1: Fill in the Blanks with right word(s) only. No marks will be awarded if you write some right some wrong, or leave any blank. [1X14]

a) Exceptionally pure and high-quality optical fibers should not contain impurities and other defects that _____, _____, and _____the light beam.

b) Visible color of nonmetals can be explained by two main mechanisms; _____ and _____of lights.

c) A single-crystal transparent Al_2O_3 can be converted to translucent and opaque specimens by incorporating _____ and _____, respectively w/o changing purity.

d) Transitions of electron from one energy state to another may imvolve the _____ and _____ of electromagnetic radiation.

e) Cadmium sulfide (CdS), having a band gap of 2.4 eV, is opaque to the radiations having wavelengths _____ than _____ μm.

f) The thermal shock resistance is best for ceramics that have high values of _____ and _____, and low values of _____ and _____.

g) Saturation magnetization is determined only by the _____ of the material, However, susceptibility and coercivity depends more on _____.

h) Two conditions to become a polymer conductive are presence of _____ bonds and _____.

i) The Fe-C phase diagram (Fig. 7.24, Callister) shows _____ invariant points correspond to the decreasing order of temperatures at _____, _____, and _____, respectively.

j) Increase of C in carbon steel _____ the critical cooling rate and _____ the martensite start/finish temperature.

k) According to the SAE designation the carbon and alloy steels are designated by a _____ number, where _____ digits indicate the amount of carbon.

l) According to the Fermi–Dirac distribution function one definition of Fermi energy could be the energy level which has a _____ probability of getting occupied by an electron at _____temperature.

m) The nature of a dislocation (i.e., edge, screw, or mixed) is defined by the relative orientations of _____ and _____.

n) Recrystallization temperature is the temperature at which recrystallization just reaches completion in _____ and it is about _____ of absolute melting temperature.

Q2: Conceptual/Short Questions. Conceptually Clear & technical language a must. More than 2-3 lines per explanation will not be checked. Don't write outside the space provided. [3X12]

a) Total Internal reflection in optical fibers is accomplished by varying the index of refraction of the core and cladding glass materials. 'step-index' or 'step-index'-which one is preferable? Why? Explain clearly the causes and effects.

b) The visible **green light** has a **wavelength** of about 510 nm. Green glass (generally Cr^{3+} doped) absorption maxima is ~ 500-600 nm (Fig. 21.8 Callister). Why then this glass appears as green? Explain.

c) Sapphire (Al_2O_3) is transparent and colorless, but ruby (Al_2O_3+ 0.5 to 2at% Cr_2O_3) is transparent and red-Why?

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

e) Generally Sapphire (Al_2O_3) could act as a Laser generator only after certain doping. Why? What other conditions must be fullfilled to prepare a laser generator?

f) The eutectic microstructure of the Pb-Sn system contains alternating layers of the α and β phases. Explain the causes of this feature. Calculate the relative layer thickness of the lamellae. Assume both phases have same density.

g) Nucleation and grain growth are two important & interconnected facts in materials processing. Make a list of phenomena (mention the main purpose/topic and provide one example for each) where both are relevant (with in the limit of your study).

h) The magnitude of C_p is almost always greater than C_v, why? Explain mathematically.

i) For isotropic materials the volumetric thermal expansion coefficient is three times the linear coefficient: $\alpha_v \approx 3\alpha_l$. Prove this relationship mathematically. Mention all necessary assumptions.

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

k) Explain the 'quantum confinement' effect for a particular material (mention name). Mention one possible application of this material and explain within 2-3 lines.

l) What should be the ideal B-H behavior for the hard and soft magnets? Plot and explain logically.

Bonus Questions (All questions must be answered before starting bonus questions) **[2 x 3]**

a) Cu containg oxides (such as $YBa_2Cu_3O_{7-x}$) can behave as a superconductor, but Cu can not be superconductor. What could be the possible causes?

b) Single crystal of 97 wt% Fe-3 wt% Si alloy fabricated such a way that a [100]-type direction is oriented parallel to the direction of an applied magnetic field is used for transformer cores-why ? Explain the causes for the special choices here.

c) Draw a clear schematic for a standard n-p-n MOSFET with proper labeling and explain the working principle **stepwise** (within 2-3 lines per step). What is the importance of oxide here?