AML120: Materials Science | Major Test
Time: 2 hours | Max. Marks: 150

Instructions:

1. Answer each question starting on a fresh page of the Answer Book.
2. Answers to all parts (a), (b), etc. of a question must be contiguous.

Some Useful Constants:

Avogadro's No.	$= 6.023 \times 10^{23}$ mol^{-1}	Boltzmann's constant	$= 1.38 \times 10^{-23}$ J K^{-1}
Gas Constant	$= 8.314$ J mol^{-1} K^{-1}	Planck's constant	$= 6.626 \times 10^{-34}$ J s
Electronic charge	$= 1.602 \times 10^{-19}$ C	Electronic mass	$= 9.109 \times 10^{-31}$ kg
1 Pa	$= 1$ N m^{-2}	1 amu	$= 1.660 \times 10^{-27}$ kg

1. *Answer any three:* 3×10

(a) There is no Face Centred Tetragonal space lattice in Bravais list. Why? Do state the considerations made by Bravais.

(b) Even when the Bragg law is satisfied, we do not observe any diffraction from (100) plane of BCC crystal. Why?

(c) A close-packed structure is formed by identical spheres of diameter, *d*. A different sphere of maximum diameter 1Å can be made to sit in this structure without causing any distortion. Estimate the diameter, *d*.

(d) A cylindrical specimen of rubber 15 cm long and 2 mm in diameter has 5×10^{18} cross links. Estimate the force needed to stretch the rubber to double its length at room temperature.

2. *Answer any three:* 3×10

(a) In a polycrystalline specimen, the mean grain diameter is 11 μm. Estimate the corresponding ASTM no. for the grain size.

(b) In a tensile test, mild steel shows sharp yield point while aluminium does not. How do we estimate a stress value corresponding to the yield strength in aluminium and what do we call it?

(c) Calculate the spacing between dislocations in a tilt boundary in FCC Pt, when the angle of tilt is 4°. The lattice parameter of Pt. is 3.92 Å.

(d) In Fe-Fe_3C system at eutectoid temperature, calculate the number of variables and the degrees of freedom.

(e) In a eutectic system A-B, there is complete solubility in the liquid state while there is no solubility in the solid state. Make a schematic sketch of this diagram and label the phase fields.

3. *Answer any three:* 3×10

(a) As a rule of thumb, we say that the diffusion distance is $\sqrt{Dt}$. Explain with the help of a diffusion couple, what concentration does it refer to? You can assume erf $(z) \approx z$.

(b) List five desirable properties of a material to be used as a heating element in a furnace.

(c) List three changes in the microstructure that occur during over-ageing and show that it leads to softening.

(d) The electrical resistivity of Fe increases from 1.6×10^{-7} to 7.1×10^{-7} ohm m on alloying with 4% Si. Estimate the change in eddy current losses for this change in composition of the transformer core.

(e) A long fibre composite of C-C fibre has its Young's modulus along the fibres as 150 GPa. For the same composite, estimate the Young's modulus perpendicular to the fibres. The moduli of the matrix and the fibre are 8 and 400 GPa, respectively

4. List all the slip systems in FCC crystals. Which ones of these will operate if tensile stress is applied along $[1\,\bar{2}\,1]$? What is the yield strength of the crystal if its CRSS is 1.5 MPa? 20

5. In a large glass plate, there are interior cracks ranging from 0.2 to 2 μm and surface scratches ranging from 0.1 to 0.7 μm deep. Adsorption at the surface causes the surface energy to reduce to 60% of its value. Which of these flaws would cause fracture on increasing the applied stress and at what value of the stress? Young's modulus of glass is 70 GPa and surface energy is 1 J m^{-2}. 10

6. The mean collision time for electron scattering in Cu at room temperature is 2.2×10^{-14} s. Cu is FCC and has a lattice parameter of 3.61 Å. Calculate the density of free electrons and the resistivity of Cu at room temperature. 10

7. Electron and hole mobilities in Si at room temperature are 0.14 and 0.05 m^2 V^{-1} s^{-1}. 10 g of n-type Si doped with As is melted together with x g of p-type Si doped with Al, both having the same dopant concentration of 10^{22} m^{-3}. You can assume that all impurities are ionized at this temperature, density of Si is not affected by the dopants and the intrinsic charge carrier density at room temperature in Si is 1.1×10^{15} m^{-3}. Calculate the conductivity of the product for values of x equal to 0, 5, 10 and 15. Which of these conductivities is the minimum and why? 20