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) Neatly sketch in a unit cell both the direction [112] and the plane $(11\bar{1})$.

(b) (331) reflection is observed from a cubic crystal at a Bragg angle of 80.5° when Cu K_α radiation of 1.54 Å is used. Determine the lattice parameter of the crystal.

(c) In FCC structure, determine the shortest distance between two octahedral holes and two tetrahedral holes in terms of atomic radius, r.

(d) Soda – lime glass has lower viscosity than the SiO_2 glass. Why?

(e) Calculate the weight fraction of S in polyisoprene rubber which is 1 % cross-linked. Atomic masses of H, C and S are 1, 12 and 32 amu, respectively

2. *Answer any three*: **3 × 10**

(a) Show that the stored grain boundary energy doubles when grain size changes from ASTM 6 to ASTM 8.

(b) A medium carbon steel (plain carbon) has 20 % grain boundary phase. Estimate the composition of the steel.

(c) A 0.4 % C steel is carburized at temperature T for 1 hour in an atmosphere having carbon equivalent to 1.0 % C at the surface of the steel. At 0.1 mm below the surface, the carbon concentration is found to be 0.6 %. How long should we carburize at this temperature so that the carbon concentration at 0.2 mm below the surface be 0.6 %. The diffusivity of carbon in steel at temperature T can be taken to be D.

(d) Differentiate between the hardness of martensite and the hardenability of steel.

(e) The nucleation rate is maximum at some intermediate temperature, T, where $T_e > T > 0$ K. Why? T_e is the equilibrium temperature where the parent and product phases coexist.

3. *Answer any three*: **3 × 10**

(a) A continuous fibre reinforced epoxy based composite is to be developed containing 30 % volume of fibres. The minimum longitudinal modulus of elasticity of the composite must be 55 GPa. Among glass, carbon and aramid fibres which possibly can be used? The modulus values for glass, carbon, aramid and epoxy are 70, 320, 120 and 3 GPa, respectively.

(b) A tensile stress of 50 MPa is applied along [112] direction in FCC crystal. Calculate the shear stress in [101] direction lying on $(11\bar{1})$ plane.

(c) When a soda glass is dipped in a hot $LiNO_3$ bath, cracks develop on the surface. Why?

(d) The resistivity of Ag (FCC; a = 4.09 Å) at room temperature is 1.6×10^{-8} ohm m. Calculate the mean collision time for electron scattering.
The total iron loss in a transformer core at normal flux density was found to be 800 W at 50 Hz and 1104 W at 60 Hz. Calculate the energy loss in a hysteresis loop.

4. The yield strength of a polycrystalline material increases from 120 MPa to 220 MPa, on decreasing the grain diameter from 0.04 mm to 0.01 mm. Calculate the yield strength of the single crystal and the Hall-Petch constant of the given material. Estimate the grain diameter if the yield strength of this polycrystalline material be 179 MPa. **15**

5. An Al_2O_3 dispersed Al alloy with dispersoids of average diameter 2000 Å has a shear yield strength of 30 MPa. If the microstructure consists of the same volume fraction of oxide particles of average diameter 200 Å, estimate the shear yield strength of this alloy. You can assume that oxide particles are unshearable. **15**

6. A 3 kW geyser, designed to operate at 100°C with 220 V power supply, uses nichrome as heating element. What is the current drawn by the geyser when it is switched on with water at 10°C? The temperature coefficient of resistivity of nichrome is 0.0001 K^{-1}. **15**

7. The resistivity of pure Si at room temperature is 3000 ohm m, calculate the intrinsic carrier density. It is doped with 10^{-6} atomic fraction of arsenic (As). Calculate the electron and hole densities in this extrinsic semiconductor. Calculate the resistivity of this material at room temperature. Electron and hole mobilities in Si are 0.14 and 0.05 $m^2\ V^{-1}\ s^{-1}$. The ionization energy of As in Si is 0.049 eV. Lattice parameter of Si (DC) is 5.43 Å. **15**