**AML 120: Materials Science** **Major Test**
**Time: 2 hour** **Max. Marks: 150**

**Instructions:**

1. Answer each question starting on a fresh page of the Answer Book.
2. Answer 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*** **15 × 3**

   (a) What are the factors that determine the density of a crystal? An elemental cubic crystal has a density of 8570 kg m$^{-3}$. The packing efficiency is 0.68. Determine the mass of one atom if the closest distance of approach between neighbouring atoms is 2.86 Å.

   (b) The Burgers vector of a mixed dislocation line in a cubic crystal is ½[110]. The dislocation line lies along the [112] direction. Find the slip plane on which this dislocation lies. Find also the screw and edge components of the Burgers vector.

   (c) For positive edge and negative screw dislocations, list in a tabular form (i) the symbols, (ii) the angular relationship between the Burgers vector **b** and **t** vector and (iii) the angular relationship between the direction of motion and the critical resolved shear stress.

   (d) Determine the amount of eutectoid ferrite and eutectoid cementite in 0.4% C steel.

2. **Answer any *three*** **15 × 3**

   (a) Hard rolled copper shows 50% recrystallization after heating for 9 minutes at 135°C or 240 minutes at 88°C. Estimate the recrystallization temperature of this copper.

   (b) State the simplest heat treatment necessary for steel to convert a 0.8% carbon steel from one structure to another:
   (i) pearlite to martensite, (ii) martensite to bainite and (iii) pearlite to bainite.

   (c) A tensile load of 100 N is applied to an aluminium-boron composite of 1 mm$^2$ cross-sectional area. The volume of the parallel fibres is 30%. What is the stress in the fibres, when the load axis is (i) parallel to the fibres, and (ii) perpendicular to the fibres? Young's moduli of aluminium and boron are 71 and 440 GPa, respectively.

   (d) The yield strength of a polycrystalline material increases from 120 MN m$^{-2}$ to 220 MN m$^{-2}$, on decreasing the grain diameter from 0.04 mm to 0.01 mm. Find the yield stress for a grain size of ASTM 9.

3. **Answer *all*** **15 × 4**

   (a) Show that the resolved shear stress reaches a maximum value, when $\varphi_1 = \varphi_2 = 45°$. Where $\varphi_1$ is the angle between the tensile axis and the slip plane normal; and $\varphi_2$ is the angle between the tensile axis and the slip direction.

   (b) A sheet of glass, with Y = 70 GPa and $\gamma = 0.5$ J m$^{-2}$, has an internal crack of length equal to 2 μm. A surface crack of 0.8 μm depth is introduced by scratching the surface with a sharp tool. Adsorption at the surface lowers the surface energy by 50%. Determine which crack will propagate first, on increasing the applied stress and at what value of the stress?

   (c) Calculate the resistivity of Al (FCC, a = 4.05 Å, atomic number = 13) at 300 K. The mean collision time for electron scattering is $2.2 \times 10^{-14}$ s at this temperature. What is the drift velocity of electrons in this conductor when the electric field of 100 V m$^{-1}$ is applied?

   (d) The resistivity of intrinsic Si at 300 K is 3000 ohm m. Calculate the intrinsic carrier density at 300 K. Assuming that the number of electrons near the top of the valence band available for thermal excitation is $2 \times 10^{25}$ m$^{-3}$, calculate the energy gap for Si. Mobilities of electrons and holes are 0.14 and 0.05 m$^2$ V$^{-1}$ s$^{-1}$, respectively.