Ph.D. Admission 20XX-XX Semester X

Written Examination

Materials Science & Engineering Department, IIT Kanpur

Date of Examination: XX XXXX 20XX

Timing: XX:XX – XX:XX XX

Application# _____

Maximum Points: 60

Please read these instructions carefully

- Any unauthorised materials, such as books, paper, documents and electronic devices with communication and/or storage capabilities are not to be brought into the examination hall.
- Handphones brought into the examination hall must be switched off at **ALL** times.
- **Do NOT** turn over the question paper placed on your desk until instructed to do so at the time of commencement of the examination.
- You are not allowed to communicate by word of mouth or otherwise with other candidate.
- Please raise your hand if you wish to communicate with an invigilator. Unless granted permission by an invigilator, you are not allowed to leave your seat.
- Once you have entered the examination hall, you will not be allowed to leave the hall until the end of examination.
- **Do NOT** continue to write after the examination has ended. You are to remain seated quietly while your answer scripts are being collected and counted.

Type of Examination

- Closed Book: **No** reference materials, in whatever format, are allowed.
- Calculators are allowed in the examination. However, **memory should be cleared, prior to examination.**
- A candidate who is suspected of cheating in examination is liable to disciplinary action including expulsion from the examination hall.

Paper Structure

- This paper consists of **four sections**, viz. A, B, C and D.
- All sections carry equal points. **No** negative marking
- Among various sections, A and B are **compulsory** while candidate has an option to **choose either C or D section**.
- Use the back side of the paper for the rough work.

For Examiner's purposes only

Section	Points
A	
B	
C	
D	

SECTION A

(Aptitude and Mathematics)

Q. 1. Count the number of squares in the figure below: **[2 points]**

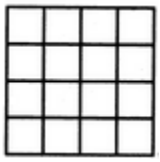

Figure 1

a) 16
b) 17
c) 25
d) 30

Q.2. Mitali walked for 70 m east from point A, then, she turned right and walked for 30 m, and then again turned right and walked for 30 m. Finally, she turned right and walked for 30 m. How far is she from the starting point? **[2 points]**

a) 170 m
b) 110 m
c) 40 m
d) 30 m

Q.3. There are 48 socks in a drawer (19 blue, 15 black and 14 red). There was power outage and it is completely dark. How many socks must the person take out to make 100 per cent certain that there is a pair of black socks? **[2 points]**

a) 48
b) 35
c) 34
d) 33

Q.4. There are two fans, two tube-lights and a projector on the ceiling. Two tube-lights are separated by two dissimilar objects, and two fans are also separated by two dissimilar objects. Find the location of the projector. **[2 points]**

a) Fourth from left
b) Third from right
c) Second from left
d) Second from right

Q. 5. A train moving at 50 km/h meets another train moving in opposite direction at 40 km/h. A passenger sitting in the first train observed that the second train took exactly 8.4 seconds to pass him. How long is the second train? **[2 points]**

a) 55 m
b) 105 m
c) 160 m
d) 210 m

Q.6. Plot $y = 1/(x-1)$ in the range $-10 < x < 10$. **[2 points]**

Q.7. Find the angle between the two vectors **u** and **v,** where **u**=**i**+**j**+**k** and **v**=**i**-**j**+**k**, and **i**, **j**, **k** are the unit vectors along x, y and z axis, respectively. **[2 points]**

Q.8. Given $x + y = k$ (k is a constant) and $z = x^2 + y^2$. Find the minimum value of z. **[2 points]**

Q.9. Solve the differential equation: $d^3y/dx^3 = 0$, given that $y = 3$ at $x=0$, $dy/dx = 4$ at $x = 1$ and $d^2y/dx^2 = 6$ at $x = 2$. **[2 points]**

Q.10. Find the amplitude and the phase of the complex number: $z=3+3i$, where $i^2=-1$ **[2 points]**

SECTION B

(Materials Science)

Q.1. X-ray ($\lambda = 0.7136$ Å) diffraction of first peak of Al (fcc crystal) is obtained at 2θ of 17.54^{o}. The lattice parameter of Al is. **[2 points]**

a) 1.18 Å
b) 2.34 Å
c) 3.31 Å
d) 4.05 Å

Q.2. Copper has an fcc structure *with an atomic radius of* 1.278 Å. Calculate the density of copper crystal. Given that atomic weight of copper 63.5 g-mol/mol and Avogadro number = 6.023×10^{23}. **[2 points]**

a) 2.01 g/cm^3
b) 8.93 g/ cm^3
c) 201.7 g/cm^3
d) 893 g/cm^3

Q.3. For a 4-phase equilibrium in Cu-Ni-Zn system, how many variables can be independently varied at constant pressure without affecting the equilibrium? **[2 points]**

a) 0 b) 1 c) 2 d) 3

Q.4. At one atmospheric pressure, the enthalpy of fusion and entropy of fusion of niobium at its equilibrium melting point are 26.478 kJ/mol and 9.656 J/mol-K respectively. Determine the equilibrium melting temperature of niobium at one atmospheric pressure. **[2 points]**

a) 2350 °C b) 2596 °C c) 2469 °C d) 2391 °C

Q.5. Draw $(\bar{1}10)$ plane in the lattice given below. **[2 points]**

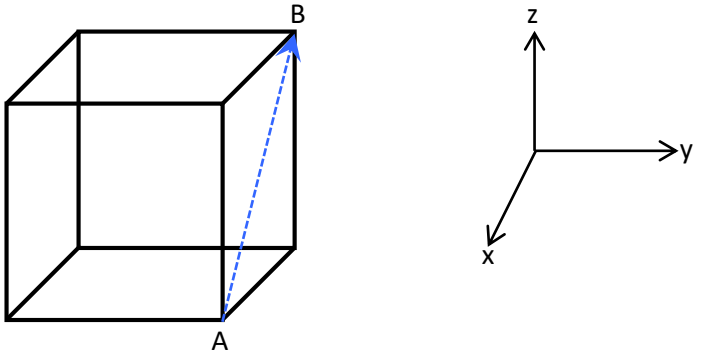

Figure 2

Q.6. Write the Miller indices for the direction AB indicated in the above lattice. **[2 points]**

Q.7. Diffusivity of an element A in the matrix of B was found to be 2.8 x 10^{-13} m^2/s and 6.2 x 10^{-12} m^2/s at 1000 °C and 1200 °C respectively. Determine the activation energy for diffusion of A in B. Given Gas constant (R) =8.314 $J.K^{-1}mol^{-1}$ & N_A = 6.023 × 10^{23} mol^{-1} **[2 points]**

a) 241 kJ/mol b) 141 kJ/mol c) 191kJ/mol d) 291kJ/mol

Q.8. Which of the following notations correctly denotes a vacancy on a calcium sub-lattice in calcium oxide (CaO)? **[2 points]**

a) $V_{Ca}^{\bullet}$ b) $V_{Ca}^{\bullet\bullet}$ c) $V_{Ca}^{\prime}$ d) $V_{Ca}^{\prime\prime}$

Q.9. Which of the following can be a thermodynamically stable defect in a crystalline solid? **[2 points]**

a) Dislocation b) Grain boundary c) Substitutional impurity d) Triple junction

Q.10. What is the equilibrium pearlite fraction of 0.4 wt.% C steel just below the eutectoid temperature, at which the equilibrium concentration of ferrite is 0.08 wt.% C. The eutectoid point is 727ºC and 0.8 wt.% C.

a) 44.4% b) 55.6% c) 50% d) cannot be determined

SECTION C

(Electronic Properties of Materials)

Q.1. If $1x10^{16}/cm^3$ boron (B) atoms are added to intrinsic silicon, silicon becomes: **[2 points]**

(a) p-type, (b) n-type, (c) direct band gap (d) highly conducting

Q.2. In an intrinsic semiconductor, upon increasing temperature (check all correct statements): **[2 points]**

(a) Mobility decreases
(b) Mobility increases
(c) Conductivity increases
(d) Conductivity decreases

Q.3. Magnetic susceptibility of a superconductor is: **[2 points]**

(a) 0 (b) -1 (c) 1 (d) ∞

Q.4. Copper (Cu) atom has one unpaired electron ($4s^1$). Cu is: **[2 points]**

(a) ferromagnetic, (b) diamagnetic, (c) anti-ferromagnetic, (d) paramagnetic

Q.5. A hypothetical semiconductor has band gap of 1.0 eV and intrinsic carrier density ($n_i = 1.5\times10^{10}/cm^3$) at 300 K. What will be intrinsic carrier density at 1200 K? If the mobility of electrons and holes is 500 cm^2/Vs and 200 cm^2/Vs respectively, what is the conductivity of semiconductor at 300 K and 1200 K? (assume mobilities do not change with temperature.) **[2 points]**

Q.6. The temperature of antiferromagnetic-to-paramagnetic transition is called: **[2 points]**

(a) Curie temperature

(b) Debye temperature

(c) Neel temperature

(d) Curie-Weiss temperature

Q.7. How does density of states $g(\mathcal{E})$ changes with energy $\mathcal{E}$ for 3-D materials. **[2 points]**

(a) $\mathcal{E}^{1/2}$ (b) $\mathcal{E}^{3/2}$ (c) $\mathcal{E}^{3}$ (d) $\mathcal{E}^{0}$

Q.8. The conductivity of an intrinsic semiconductor **[2 points]**

(a) increases with temperature

(b) increases and then decreases with temperature

(c) remains constant

(d) decreases with temperature

Q.9. The resistivity of pure silicon at room temperature is 3000 ohm.m. Calculate the intrinsic carrier density. Given mobility ($m^2/V/s$) of electron = 0.14 and hole = 0.05 at room temperature. **[2 points]**

Q.10. At room temperature the electrical conductivity and the electron mobility for Aluminium are 3.8×10^7 $(\Omega.m)^{-1}$ and 0.0012 $m^2V^{-1}.s^{-1}$, respectively. What is the number of free electrons per aluminium atom? Assume a density of 2.7 g/cm^3 and atomic weight of 26.98 g/mol.

[2 points]

SECTION D

(Mechanical Properties of Materials)

Q.1. Choose correct statements **[2 points]**

a) For an edge dislocation, the Burgers vector is perpendicular to the dislocation line and the dislocation moves in a direction parallel to the Burgers vector.
b) For an edge dislocation, the Burgers vector is perpendicular to the dislocation line and the dislocation moves in a direction perpendicular to the Burgers vector.
c) For a screw dislocation, the Burgers vector is parallel to the dislocation line and the dislocation moves in a direction parallel to the Burgers vector.
d) For a mixed dislocation, the Burgers vector is parallel to the dislocation line and the dislocation moves in a direction perpendicular to the Burgers vector.

Q.2. High strength and significant ductility can be achieved by **[2 points]**

(a) Precipitation hardening

(b) Solid solution strengthening

(c) Hall-Petch strengthening

(d) strain hardening

Q.3. The major difference between high cycle fatigue (HCF) and low cycle fatigue (LCF) is **[2 points]**

a) Nominal strain in LCF is elastic while it is plastic in HCF.
b) Number of cycles is low in HCF and high in LCF.
c) HCF is stress controlled while LCF is strain controlled.
d) HCF is strain controlled while LCF is stress controlled.

Q.4. What is the relation between elastic modulus (E) and shear modulus (G) for an isotropic cubic material? [**2 points**]

Q.5. Find the ultimate tensile strength UTS for a steel sample with constitutive equation $\sigma = 500\,\varepsilon^{0.2}$ where all units are in MPa. [**2 points**]

Q.6. Fill in the blanks **[2×4 = 8 points]**

a) The Orowan equation that relates the strain rate ($\dot{\gamma}$) with dislocation velocity (v) is given by _____.

b) Energy of _____ dislocation is lower than _____ dislocation and therefore equilibrium density of _____ dislocation is lower than _____ dislocation.

c) Higher the distance between the partials _____ is the Stacking Fault Energy.

d) Nabarro-Herring creep is operative at _____ temperature compared to Coble creep at a given grain size and for a given temperature, Coble creep is favoured over Nabarro-Herring creep at_____grain size.