C : Materials Science

Q. 1 – Q. 9 carry one mark each.

Q.1 Energy Dispersive Spectroscopy (EDS) in a typical scanning electron microscope enables elemental identification by collecting and examining which of the following:

(A) Secondary electrons from the sample
(B) Back scattered electrons from the sample
(C) Characteristic X-rays from the sample
(D) Diffraction pattern from the sample

Q.2 Which of the following rotational symmetry is forbidden in a perfectly periodic 3-dimensional lattice?

(A) 1-fold (B) 3-fold (C) 5-fold (D) 6-fold

Q.3 Which of the following thermodynamic properties shows a discontinuity during a second-order phase transition?

(A) Volume (B) Enthalpy
(C) Entropy (D) Heat capacity

Q.4 Cross slip is easily promoted in metals having

(A) a low stacking fault energy. (B) a low grain boundary energy.
(C) a high stacking fault energy. (D) a high grain boundary energy.

Q.5 For a typical metal at room temperature and atmospheric pressure, the Fermi energy is defined as the energy level for which the probability of occupancy is:

(A) 0 (B) 0.25 (C) 0.5 (D) 1

Q.6 Number of elements in a tensor of rank 4 is _____.

Q.7 Which one of the following effects is the working principle of a thermocouple?

(A) Thomson (B) Seebeck (C) Peltier (D) Meissner

Q.8 At equilibrium, the maximum number of phases that can coexist in a ternary system at constant pressure is _____.

Q.9 Defect-free single crystal alumina (sapphire) is

(A) opaque and white. (B) transparent.
(C) translucent. (D) opaque and black.

Q. 10 – Q. 22 carry two marks each.

Q.10 Match the following processes and the products obtained:

P: Mechanical attrition	1: Thin films
Q: Physical vapour deposition	2: Plastics
R: Injection moulding	3: Nanoparticles
S: Sintering	4: Rails
	5: Carbide tools

(A) P-1, Q-2, R-3, S-5
(B) P-3, Q-1, R-2, S-5
(C) P-4, Q-1, R-3, S-2
(D) P-3, Q-4, R-1, S-2

Q.11 In a diffraction experiment, monochromatic X-rays of wavelength 1.54 Å are used to examine a material with a BCC structure. If the lattice parameter is 4.1 Å, the angular position θ of the first diffraction peak is _____ degrees.

Q.12 The yield strength of a ferritic steel increases from 120 MPa to 150 MPa when the grain size is decreased from 256 μm to 64 μm. When the grain size is further reduced to 16 μm, the expected yield strength is _____ MPa.

Q.13 A direct bandgap semiconductor has a bandgap of 1.8 eV. The threshold value of the wavelength **BELOW** which this material will absorb radiation is_____ Å.
(Given: Planck's constant, $h = 6.626 \times 10^{-34}$ J s, the charge of an electron, $e = 1.6 \times 10^{-19}$ C, and speed of light, $c = 3 \times 10^{8}$ m s^{-1})

Q.14 A half cell consisting of pure Ni immersed in an aqueous solution containing Ni^{2+} ions of unknown concentration, is galvanically coupled with another half cell consisting of pure Cd immersed in a 1 M aqueous solution of Cd^{2+} ions. The temperature is 25 ^{o}C and pressure is 1 atm. The standard electrode reduction potentials of Ni and Cd are –0.250 V and –0.403 V, respectively. The voltage of the cell is found to be zero. The concentration of Ni^{2+} in the solution is _____ $\times 10^{-6}$ M.
(Given: Universal gas constant, $R = 8.31$ J mol^{-1} K^{-1}, Faraday's constant, $F = 96500$ C mol^{-1})

Q.15 Match the type of magnetism given in Group 1 with the material given in Group 2:

Group 1	Group 2
P: Ferromagnetic	1: Nickel oxide
Q: Ferrimagnetic	2: Sodium
R: Antiferromagnetic	3: Magnetite
S: Paramagnetic	4: Cobalt

(A) P-4, Q-3, R-1, S-2
(B) P-4, Q-1, R-3, S-2
(C) P-1, Q-2, R-4, S-3
(D) P-3, Q-2, R-1, S-4

Q.16 Gallium is to be diffused into pure silicon wafer such that its concentration at a depth of 10^{-3} cm will be one half the surface concentration. Given that the diffusion coefficient (D) of gallium in silicon at 1355 °C is 6×10^{-11} cm^2 s^{-1}, the time the silicon wafer should be heated in contact with gallium vapour at 1355 °C is _____ s.
(Given: $erf(0.5) \cong 0.5$)

Q.17 A batch of spherical titania nanoparticles, uniform in size, has a specific surface area of 125 $m^2\ g^{-1}$. If the density of titania is 4.23 g cm^{-3}, the diameter of the particles is _____ nm.

Q.18 Given the probability distribution function

$$f(x) = \begin{cases} 0.25x \text{ for } 1 \le x \le 3 \\ 0 \text{ otherwise} \end{cases}$$

The probability that the random variable x takes a value between 1 and $\sqrt{5}$ is _____.

Q.19 In the vulcanization of 50 g of natural rubber, 10 g of sulfur is added. Assuming the mer to S ratio is 1:1, the maximum percentage of cross-linked sites that could be connected is _____%. (Given: atomic weight of S is 32 amu and molecular weight of a mer of natural rubber is 68 amu)

Q.20 Match the heat treatment process of steels given in Group 1 with the microstructural feature given in Group 2:

Group 1	Group 2
P: Quenching	1: Bainite
Q: Normalizing	2: Martensite
R: Tempering	3: Pearlite
S: Austempering	4: Iron carbide precipitates
	5: Intermetallic precipitates

(A) P-2, Q-3, R-4, S-1
(B) P-3, Q-4, R-5, S-1
(C) P-4, Q-1, R-5, S-3
(D) P-2, Q-5, R-4, S-3

Q.21 In the photoelectric effect, electrons are ejected

(A) at all wavelengths, as long as the intensity of the incident radiation is above a threshold value.
(B) at all wavelengths, as long as the intensity of the incident radiation is below a threshold value.
(C) at all intensities, as long as the wavelength of the incident radiation is below a threshold value.
(D) at all intensities, as long as the wavelength of the incident radiation is above a threshold value.

Q.22 The angle between [110] and [111] directions in the cubic system is _____ degrees.

END OF THE QUESTION PAPER