Q. 1 – Q. 25 carry ONE mark each

Q.1 *Consider the following five readings from an experiment: 19, 17, 15, 13, 11. The standard deviation of the readings is________.*

Q.2 $\frac{y(x+h)-y(x)}{h}$ *is a numerical approximation for*

(A) $\frac{dy}{dx}$ (B) $\frac{dy}{dh}$ (C) $\int y\, dx$ (D) $\int x\, dy$

Q.3 *If A and B are matrices,* $(AB)^T$ =

(A) $A^T B$ (B) $B^T A$ (C) $A^T B^T$ (D) $B^T A^T$

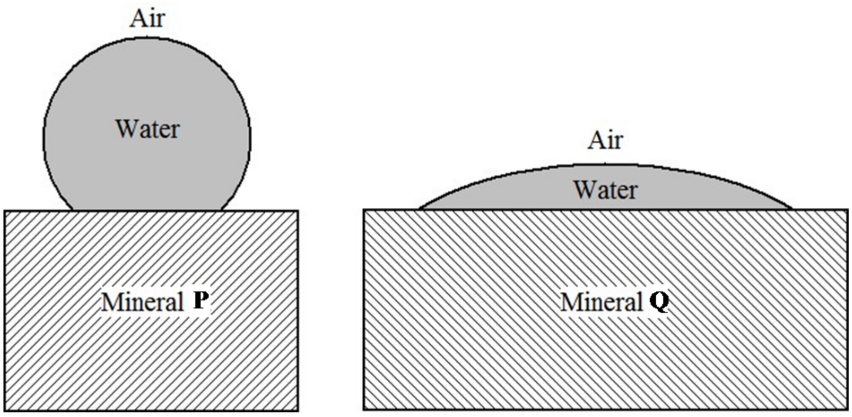
Q.4 *Which of the following properties is intensive?*

(A) Volume (B) Gibbs free energy
(C) Chemical potential (D) Entropy

Q.5 *In an Ellingham diagram, the standard free energy change* ΔG^0 *for the oxidation reaction of a metal M given by:* $xM(s) + O_2(g) \rightarrow M_xO_2(s)$ *, is plotted as a function of temperature. The slope of this line is positive because*

(A) ΔS^0 is positive (B) ΔS^0 is negative
(C) ΔH^0 is positive (D) ΔH^0 is negative

Q.6 *In froth flotation, hydrophobic mineral particles ascend with air bubbles preferentially over hydrophilic mineral particles. The figure below shows a schematic of a water droplet placed on the surfaces of two mineral P and Q.*



Given this information, pick the **CORRECT** *statement from the following:*

(A) Mineral P ascends with air bubbles preferentially over mineral Q.
(B) Mineral Q ascends with air bubbles preferentially over mineral P.
(C) Both minerals P and Q ascend with the air bubbles without preference.
(D) Both minerals P and Q sink to the bottom.

Q.7 *Which of the following oxide addition results in polymerization (i.e., network formation) in a silicate slag?*

(A) CaO (B) MgO (C) P_2O_5 (D) Na_2O

Q.8 *Zn is commercially extracted from which of the following minerals?*

(A) Sphalerite (B) Magnetite (C) Chalcopyrite (D) Galena

Q.9 *Self supporting arches for furnace roofs can be fabricated using silica bricks but not using magnesia bricks. Why?*

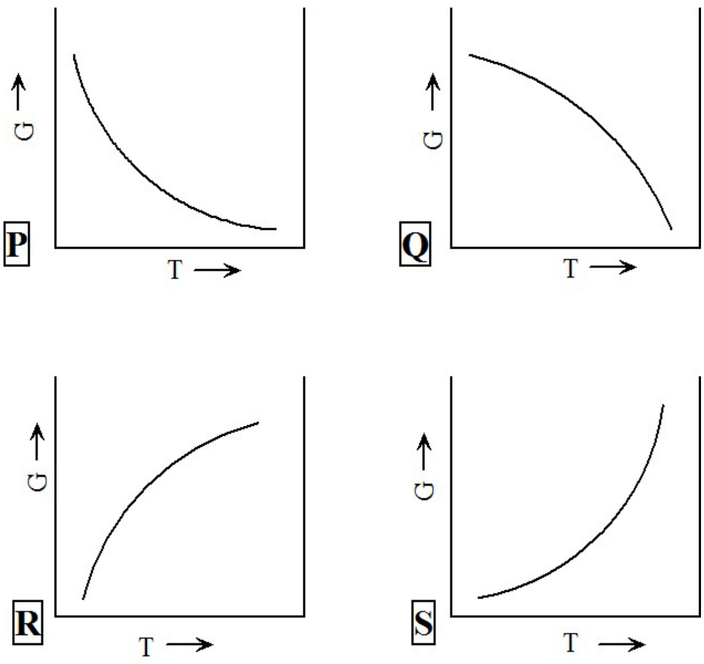
(A) Silica has a significantly lower thermal expansion coefficient than magnesia at high temperatures.
(B) Silica has a significantly higher thermal conductivity than magnesia at high temperatures.
(C) Silica has a significantly lower melting point than magnesia.
(D) Silica is significantly more acidic than magnesia.

Q.10 *A species can diffuse through the lattice (diffusion coefficient, D_L), along grain boundaries (diffusion coefficient, D_{GB}), and along free surfaces (diffusion coefficient, D_S). Which of the following relations is* **CORRECT***?*

(A) $D_L > D_{GB} > D_S$ (B) $D_S > D_L > D_{GB}$

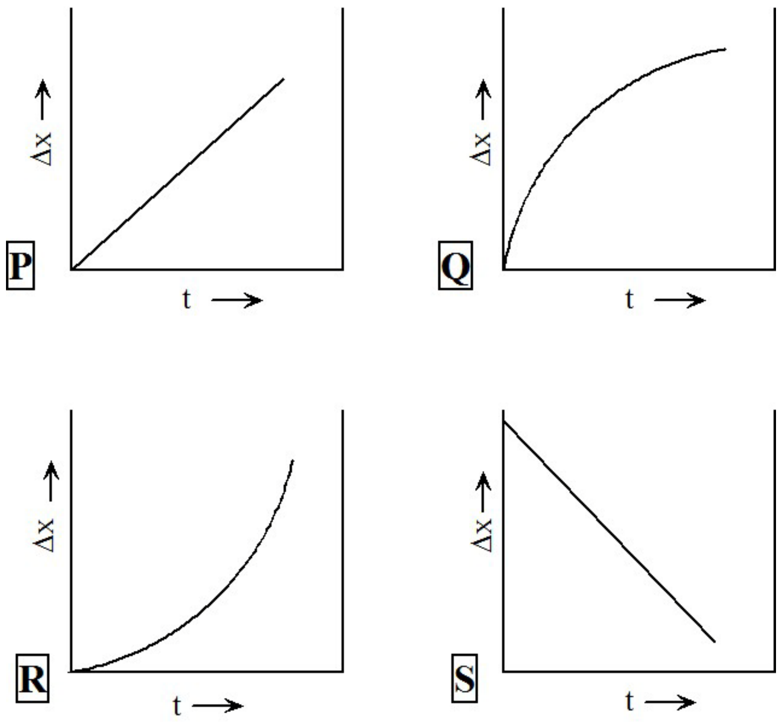
(C) $D_{GB} > D_S > D_L$ (D) $D_S > D_{GB} > D_L$

Q.11 *Select the* **CORRECT** *plot of Gibbs free energy (G) vs. temperature (T) for a single component system from the following:*



(A) P (B) Q (C) R (D) S

Q.12 *If Δx represents adherent oxide layer thickness and t is time, which of the following curves represents diffusion-controlled oxidation kinetics?*



(A) P (B) Q (C) R (D) S

Q.13 *Based on the standard galvanic series, select the* **CORRECT** *sequence of metals in the increasing order of anodic behaviour:*

(A) Zn, Fe, Pt, Cu (B) Pt, Zn, Cu, Fe
(C) Fe, Pt, Cu, Zn (D) Pt, Cu, Fe, Zn

Q.14 *In a conventional unit cell of a crystal, $a = b \neq c$ and $\alpha = \beta = \gamma = 90^o$. This crystal belongs to which of the following systems?*

(A) Cubic (B) Tetragonal (C) Orthorhombic (D) Triclinic

Q.15 *In an X-Ray powder pattern of a simple cubic crystal, the 2^{nd} peak corresponds to*

(A) (111) (B) (100) (C) (200) (D) (110)

Q.16 *When boron (trivalent) is doped to silicon, the resulting material is*

(A) a p-type semiconductor. (B) an n-type semiconductor.
(C) a superconductor. (D) an insulator.

Q.17 *Which of the following metal working operations can be categorized as an indirect compression process?*

(A) Forging (B) Wire drawing (C) Extrusion (D) Stretch forming

Q.18 *Which of the following is a typical rolling defect?*

(A) Buckling (B) Edge cracking (C) Cold shut (D) Porosity

Q.19 *Which of the following manufacturing processes is* **NOT** *used for producing fine grained metals?*

(A) Electrodeposition
(B) Czochralski method
(C) Equi-Channel Angular Pressing (ECAP)
(D) Sintering of milled powders

Q.20 *Which of the following metal forming techniques is used to produce soft drink cans from aluminium sheets?*

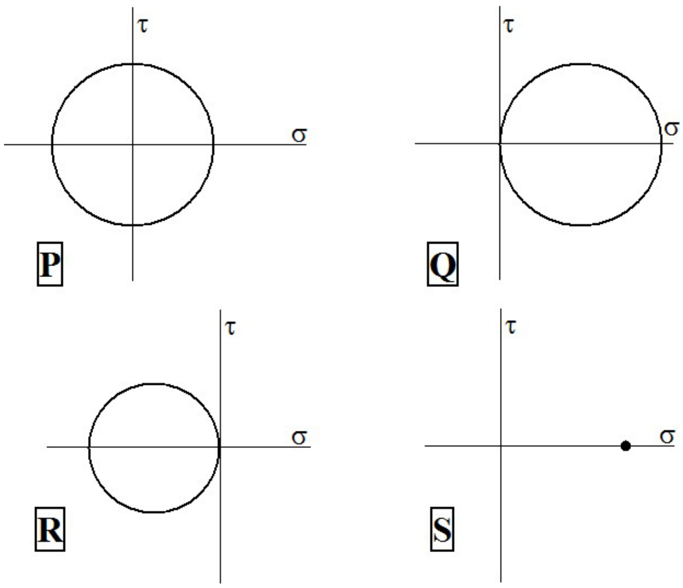
(A) Rolling (B) Forging (C) Deep drawing (D) Extrusion

Q.21 *Which of the following is* **NOT** *a solid state metal joining technique?*

(A) Ultrasonic welding (B) Friction welding
(C) Diffusion bonding (D) Electroslag welding

Q.22 *The stress required for Orowan dislocation bypass is 200 MPa in an alloy when the inter-precipitate spacing is 500 nm. In the same alloy, if the inter-precipitate spacing is reduced to 200 nm, the stress required (in MPa) is _____ .*

Q.23 *Which of the following Mohr's circles of a plane-stress condition corresponds to equi-biaxial tension?*



(A) P (B) Q (C) R (D) S

Q.24 *Select the* **INCORRECT** *statement related to the effect of a small amount of carbon addition on mechanical properties of iron.*

(A) Ductile-Brittle-Transition-Temperature (DBTT) increases.
(B) Hardenability increases.
(C) Toughness increases.
(D) Yield point phenomenon occurs.

Q.25 *In polymers such as epoxies, creep resistance can be enhanced by*

(A) increasing the bulkiness of side groups.
(B) increasing the cross-link density.
(C) addition of plasticizers.
(D) annealing.

Q. 26 – Q. 55 carry TWO marks each

Q.26 *One of the eigenvalues of the matrix* $\begin{bmatrix} -2 & 1 \\ 1 & -2 \end{bmatrix}$ *is* -3. *The other eigenvalue is* ______.

Q.27 *Consider the scalar function* $f = xyz$. *The magnitude of the gradient, i.e.* $|\nabla f|$ *at the point (0,2,2) is* _________.

Q.28 *The determinant of the matrix* $\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$ *is* _________

Q.29 *The solution of the ordinary differential equation* $\frac{dy}{dx} = 5x$ *for* $y|_{x=0} = 0$ *is*

(A) 5 (B) $\frac{5x^2}{2}$ (C) $5x^2$ (D) e^{5x}

Q.30 *The maximum value of the function* $f(x) = -x^2 + 2x$ *is* _________.

Q.31 *C (s) +* CO_2 *(g)* $\leftrightharpoons$ *2CO (g) is an important reaction in iron making.*
Given $\Delta H^0_{298} = 172000$ *joules per mole of* CO_2*, which of the following conditions will favour the forward reaction?*

(A) Increasing both temperature and pressure.
(B) Decreasing temperature and increasing pressure.
(C) Decreasing both temperature and pressure.
(D) Increasing temperature and decreasing pressure.

Q.32 *Consider the reaction:*

Fe_3O_4 *(solid, pure) + CO (gas, 1 atm)* $\rightarrow$ *3FeO (solid, pure) +* CO_2 *(gas, 1 atm)*

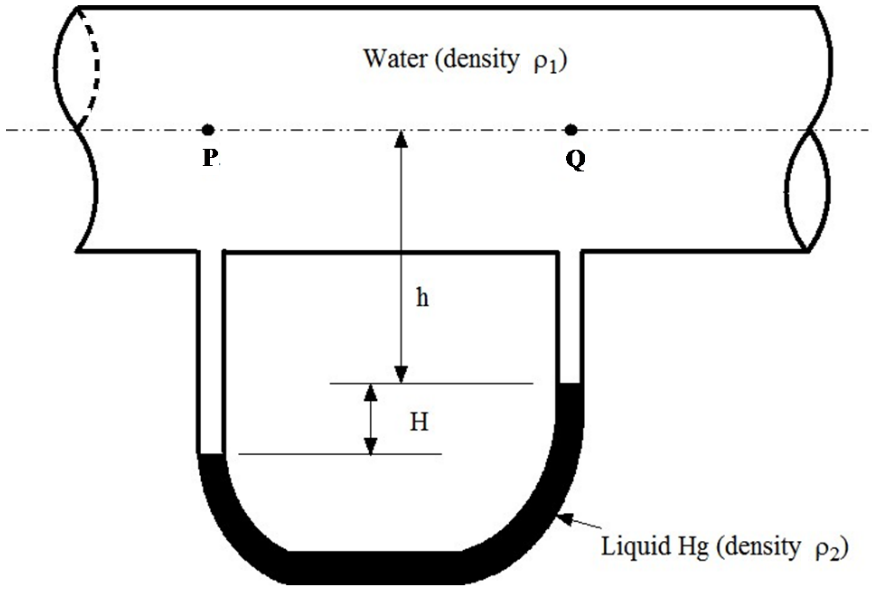
For this reaction, $\Delta G^0_{1200} = -8000$ *joules per mole of CO and R = 8.314 J* $mol^{-1}K^{-1}$.

The equilibrium ratio, p_{CO_2}/p_{CO} *for the reaction at 1200 K and 1 atm is* ______

Q.33 *An iron blast furnace produces hot metal containing 95% Fe. The iron ore charged into the furnace contains 95%* Fe_2O_3 *and the rest is gangue. Assume that all the iron in the ore goes to hot metal. The amount of iron ore (in kg) required for producing 1000 kg of hot metal is* _______ .

(Atomic weight of Fe = 56 g mol^{-1} *and that of* Fe_2O_3 *= 160 g* mol^{-1}*)*

Q.34 *The figure below shows water flowing through a pipe. The pressure difference between points P and Q measured using a water-over-mercury manometer is*



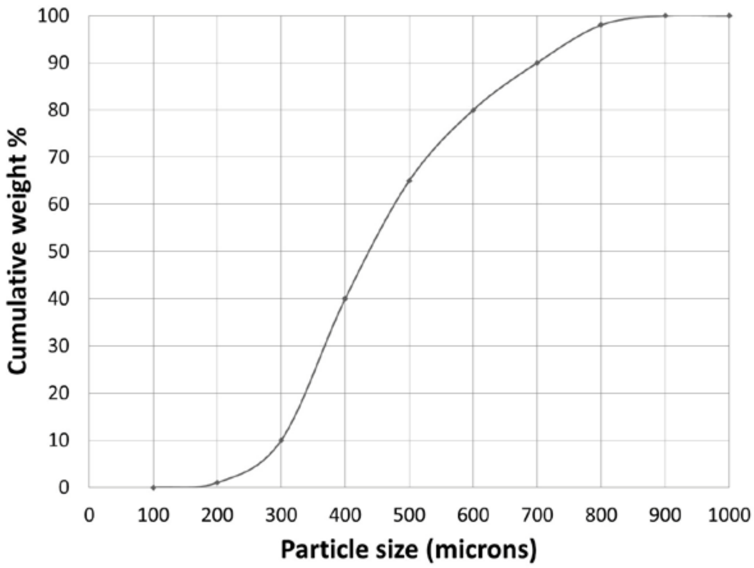
(A) $\rho_2 g H$ (B) $\rho_1 g h$
(C) $(\rho_2 - \rho_1)\ g\ H$ (D) $(\rho_2 - \rho_1)\ g\ h$

Q.35 *Match the metals listed in* **Group I** *with the most appropriate extraction routes listed in* **Group II.**

Group I	**Group II**
P. Al	*1. Blast Furnace*
Q. Ti	*2. Matte Smelting*
R. Cu	*3. Electrolysis of Fused Salts*
S. Fe	*4. Halide Metallurgy*

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

Q.36 *The figure below shows the cumulative size distribution of particles of a crushed mineral. 10 kg of this material is first passed through a sieve of size 400 micron and then through a sieve of size 300 micron. The weight of mineral (in kg) that is retained on the 300 micron sieve is ______ .*



Q.37 *In electrolytic refining of Ni, the anode is Cu-10 atom % Ni and the cathode is pure Ni. Assuming the Cu-Ni solution to be ideal, the* **ABSOLUTE** *value of the minimum voltage (in mV) required for refining is ______ .*

Given: Faraday constant = 96490 C mol^{-1}, Temperature = 300 K, R = 8.314 J mol^{-1} K^{-1}.

Q.38 *Configurational entropy due to ideal mixing in a binary A-B system is expressed as:* $\Delta S_{mix} = -R(X_A lnX_A + X_B lnX_B)$, *where X_A and X_B are mole fractions of A and B respectively.*

ΔS_{mix} *is maximum at* X_A =______

Q.39 Melting point of a metal is 1356 K. When the liquid metal is undercooled to 1256 K, the free energy change for solidification, $\Delta G^{L\rightarrow S} = -1000$ J mol^{-1}. On the other hand, if the liquid metal is undercooled to 1200 K, the free energy change (in J mol^{-1}) for solidification is _____.

Q.40 Match the names listed in **Group I** *with the reactions listed in* **Group II**

Group I	**Group II**
P. Eutectic	1. $\gamma + \beta \rightarrow \alpha$
Q. Peritectic	2. $L \rightarrow \alpha + \beta$
R. Peritectoid	3. $L_1 \rightarrow L_2 + \alpha$
S. Monotectic	4. $L + \beta \rightarrow \alpha$

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

Q.41 *It takes 10 hours to homogenize an alloy at 1273 K. The time required (in hours) to achieve the same extent of homogenization at 1373 K is _____ .*

Given: Diffusivity, $D_{1373\,K} = 10^{-18} m^2\, s^{-1}$ *and* $D_{1273\,K} = 10^{-19} m^2\, s^{-1}$

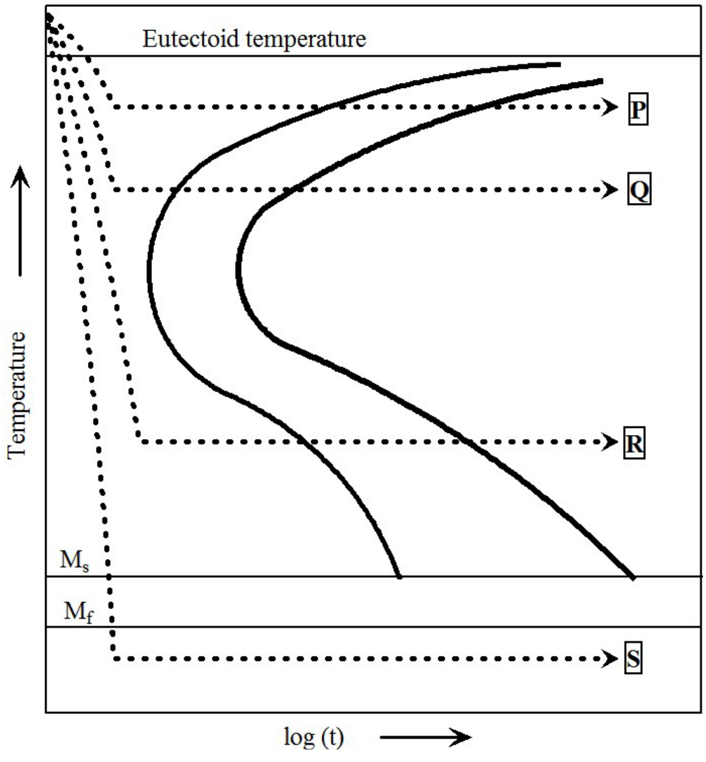
Q.42 *Match the materials listed in* **Group I** *with the most appropriate applications listed in* **Group II**

Group I	**Group II**
P. Iron-Silicon alloy	*1. Heating element*
Q. GaAs	*2. Ultrasonic generator*
R. Nichrome	*3. Transformer core*
S. Quartz crystals	*4. Light emitting diode*

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

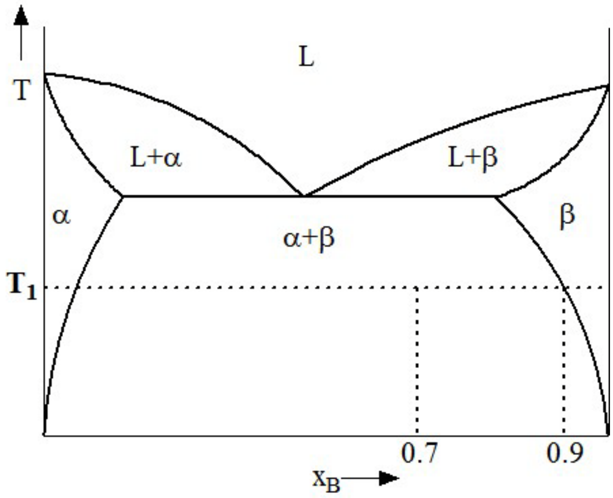
Q.43 *Match the heat treatments for an eutectoid steel shown in the TTT diagram below (as P, Q, R and S) with the resulting microstructures listed below:*

1. Fine pearlite
2. Martensite
3. Bainite
4. Coarse pearlite



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

Q.44 *An alloy of overall composition X_B=0.7 was equilibrated at temperature T_1. Microstructural analysis showed two phases, α and β, and that the phase fraction of β was 0.75. Given that the equilibrium composition of β at T_1 is 0.9 as shown in the phase diagram below, the maximum solubility of B in α (in mole fraction) at this temperature is _______.*



Q.45 *If a cylindrical billet of height 1.0 m and diameter 0.5 m is upset forged to form a cylindrical pancake of height 0.25 m, the diameter of the pancake (in m) is ______ .*

Q.46 *Determine the correctness or otherwise of the following Assertion [a] and the Reason [r]*

Assertion: In a pure metal weld, elastic modulus in the heat affected zone (HAZ) is the same as that in the base metal.

Reason: Coarse grained microstructure in the HAZ results in lower hardness.

(A) Both [a] and [r] are true and [r] is the correct reason for [a]
(B) Both [a] and [r] are true and [r] is not the correct reason for [a]
(C) Both [a] and [r] are false
(D) [a] is true but [r] is false

Q.47 *At the mould exit of a continuous caster, the metal consisting of a solidified shell with a liquid metal core exits at the rate of 35 kg s^{-1}. Given that the latent heat of fusion is 3×10^5 J kg^{-1} and the total rate of heat removal by the mould is 4.2×10^6 W, the mass fraction of solid at the mould exit is _____.*

Assume that both solid and liquid remain at the melting point while they are in the mould.

Q.48 *Match the features observed in castings listed in* **Group I** *with the most appropriate reasons listed in* **Group II**

Group I	**Group II**
P. Macrosegregation	*1. Inoculation*
Q. Fine grained structure	*2. Gas evolution and shrinkage*
R. Porosity	*3. Temperature gradients and supercooling*
S. Dendrites	*4. Density difference and convection currents*

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

Q.49 *The driving force for sintering a compact consisting of spherical particles of radius R_1 is ΔG_1. If the particle size is reduced to $R_2 = 0.1\ R_1$, the corresponding driving force $\Delta G_2 = \alpha\ \Delta G_1$, where α is* _____ .

Q.50 *Which of the following techniques are* **NOT** *applicable for detecting internal flaws in a ceramic material?*

1. Liquid penetration test
2. Radiography
3. Ultrasonic testing
4. Eddy current method

(A) 1 and 3 (B) 3 and 4 (C) 2 and 4 (D) 1 and 4

Q.51 *Match the following fracture surface features listed in* **Group I** *with the fracture mechanisms listed in* **Group II**

Group I	**Group II**
P. Striations	*1. Intergranular fracture*
Q. Dimples and microvoids	*2. Cleavage fracture*
R. Flat facets and "river markings"	*3. Ductile fracture*
S. Jagged surface with grain-like features	*4. Fatigue fracture*

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

Q.52 *Match the scientist pairs listed in* **Group I** *with phenomena listed in* **Group II**

Group I	**Group II**
P. Hall-Petch	*1. Dislocation reaction product*
Q. Nabarro-Herring	*2. Diffusional creep*
R. Lomer-Cottrell	*3. Dislocation source*
S. Frank-Read	*4. Grain boundary strengthening*

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

Q.53 *In an FCC crystal, the strain energy per unit length of a dislocation with Burgers vector* $\frac{a}{2}\langle 110\rangle$ *is* _____ *times that of a* $\frac{a}{6}\langle 112\rangle$ *dislocation.*

Q.54 *Match the desired mechanical properties listed in* **Group I** *with the microstructural features listed in* **Group II**

Group I	**Group II**
P. Creep resistance	*1. Fine grained two-phase microstructure*
Q. Elastic modulus enhancement	*2. Single crystal*
R. Superplasticity	*3. Coherent precipitates*
S. Increased strength	*4. Glass fibres in epoxy*

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

Q.55 *A brittle material is mechanically tested in medium P in which it has surface energy* $\gamma_S = 0.9\ J\ m^{-2}$. *This material has a fracture strength of 300 MPa for a given flaw size. The same solid containing the same flaws is then tested in medium Q in which* $\gamma_S = 0.1\ J\ m^{-2}$. *The fracture strength (in MPa) in medium Q based on Griffith's theory is* _________ .

END OF THE QUESTION PAPER