

Q. 1 – Q. 5 carry one mark each.

Q.1 The fishermen, _____ the flood victims owed their lives, were rewarded by the government.

- (A) whom (B) to which (C) to whom (D) that

Q.2 Some students were not involved in the strike.

If the above statement is true, which of the following conclusions is/are logically necessary?

1. Some who were involved in the strike were students.
2. No student was involved in the strike.
3. At least one student was involved in the strike.
4. Some who were not involved in the strike were students.

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

Q.3 The radius as well as the height of a circular cone increases by 10%. The percentage increase in its volume is _____.

- (A) 17.1 (B) 21.0 (C) 33.1 (D) 72.8

Q.4 Five numbers 10, 7, 5, 4 and 2 are to be arranged in a sequence from left to right following the directions given below:

1. No two odd or even numbers are next to each other.
2. The second number from the left is exactly half of the left-most number.
3. The middle number is exactly twice the right-most number.

Which is the second number from the right?

- (A) 2 (B) 4 (C) 7 (D) 10

Q.5 Until Iran came along, India had never been _____ in kabaddi.

- (A) defeated (B) defeating (C) defeat (D) defeatist

Q. 6 – Q. 10 carry two marks each.

- Q.6 Since the last one year, after a 125 basis point reduction in repo rate by the Reserve Bank of India, banking institutions have been making a demand to reduce interest rates on small saving schemes. Finally, the government announced yesterday a reduction in interest rates on small saving schemes to bring them on par with fixed deposit interest rates.

Which one of the following statements can be inferred from the given passage?

- (A) Whenever the Reserve Bank of India reduces the repo rate, the interest rates on small saving schemes are also reduced
- (B) Interest rates on small saving schemes are always maintained on par with fixed deposit interest rates
- (C) The government sometimes takes into consideration the demands of banking institutions before reducing the interest rates on small saving schemes
- (D) A reduction in interest rates on small saving schemes follow only after a reduction in repo rate by the Reserve Bank of India

- Q.7 In a country of 1400 million population, 70% own mobile phones. Among the mobile phone owners, only 294 million access the Internet. Among these Internet users, only half buy goods from e-commerce portals. What is the percentage of these buyers in the country?

- (A) 10.50 (B) 14.70 (C) 15.00 (D) 50.00

- Q.8 The nomenclature of Hindustani music has changed over the centuries. Since the medieval period dhrupad styles were identified as baanis. Terms like gayaki and baaj were used to refer to vocal and instrumental styles, respectively. With the institutionalization of music education the term gharana became acceptable. Gharana originally referred to hereditary musicians from a particular lineage, including disciples and grand disciples.

Which one of the following pairings is NOT correct?

- (A) dhrupad, baani
- (B) gayaki, vocal
- (C) baaj, institution
- (D) gharana, lineage

- Q.9 Two trains started at 7AM from the same point. The first train travelled north at a speed of 80km/h and the second train travelled south at a speed of 100 km/h. The time at which they were 540 km apart is _____ AM.

- (A) 9 (B) 10 (C) 11 (D) 11.30

- Q.10 “I read somewhere that in ancient times the prestige of a kingdom depended upon the number of taxes that it was able to levy on its people. It was very much like the prestige of a head-hunter in his own community.”

Based on the paragraph above, the prestige of a head-hunter depended upon _____

- (A) the prestige of the kingdom
- (B) the prestige of the heads
- (C) the number of taxes he could levy
- (D) the number of heads he could gather

END OF THE QUESTION PAPER

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Q. 1 – Q. 25 carry one mark each.

Q.1 One of the eigenvalues for the following matrix is _____.

$$\begin{bmatrix} a & 2 \\ 8 & a \end{bmatrix}$$

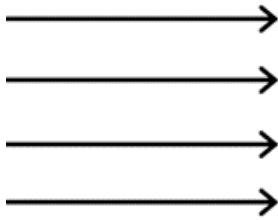
(A) $a - 4$

(B) $-a - 4$

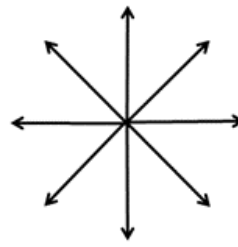
(C) 4

(D) -4

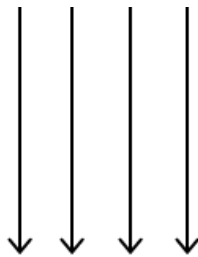
Q.2 The curl of vector fields shown below is **not** zero for _____.



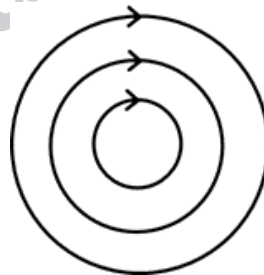
(A)



(B)



(C)



(D)

Q.3 The smallest period of function $f(x) = \sin\left(\frac{nx}{k}\right)$ is _____.

(A) 2π

(B) $\frac{k}{n}$

(C) $\frac{2\pi k}{n}$

(D) $\frac{2\pi n}{k}$

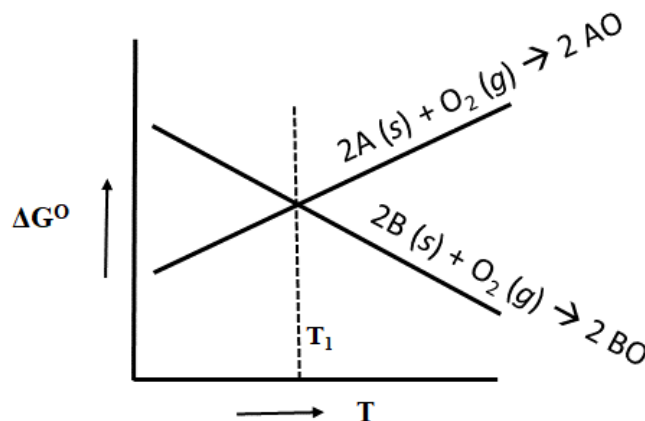
Q.4 The directional derivative of $\phi = x^2 + y$ along the unit vector $\hat{u} = \frac{1}{5}(3\hat{i} + 4\hat{j})$ at (1,1) is _____.

- (A) 3 (B) 2
(C) 1 (D) 0

Q.5 Liquid steel is kept in a graphite crucible for sufficiently long time such that equilibrium is established. Activity of carbon (with respect to graphite as the standard state) in the liquid is _____.

- (A) 0.0 (B) 0.5 (C) 1.0 (D) 2.0

Q.6 The variation of standard free energies for two oxides AO and BO with temperature are shown below.



The correct statement with reference to the above figure is _____.

- (A) AO is a gas
(B) BO is a gas
(C) A will reduce BO above temperature T_1
(D) B will reduce AO below temperature T_1

- Q.7 Terminal rise velocity of a spherical shaped solid in a liquid obeys the following functional relationship:

$$U = f(d, W, \mu, \rho)$$

Where, U is the terminal rise velocity, d is the diameter of the solid, W is the apparent weight of the solid, μ is the viscosity of liquid and ρ is the density of liquid.

According to Buckingham Π theorem, the number of independent dimensionless variables needed to describe the phenomenon is _____.

- (A) 1 (B) 2 (C) 3 (D) 5

- Q.8 Consider electrodeposition of copper on a copper electrode from an aqueous solution containing $0.5 \times 10^{-3} \text{ mol.cm}^{-3}$ CuSO_4 .

Given: Faraday constant, $F = 96500 \text{ Coulomb per gram equivalent}$.

Assume transport of reactant is rate limiting, and mass transfer coefficient is $10^{-4} \text{ cm.s}^{-1}$.

The limiting current density (in mA.cm^{-2}) is _____.

- (A) 4.83 (B) 9.65 (C) 19.30 (D) 38.60

Q.9 The correct sequence of steelmaking operations is _____.

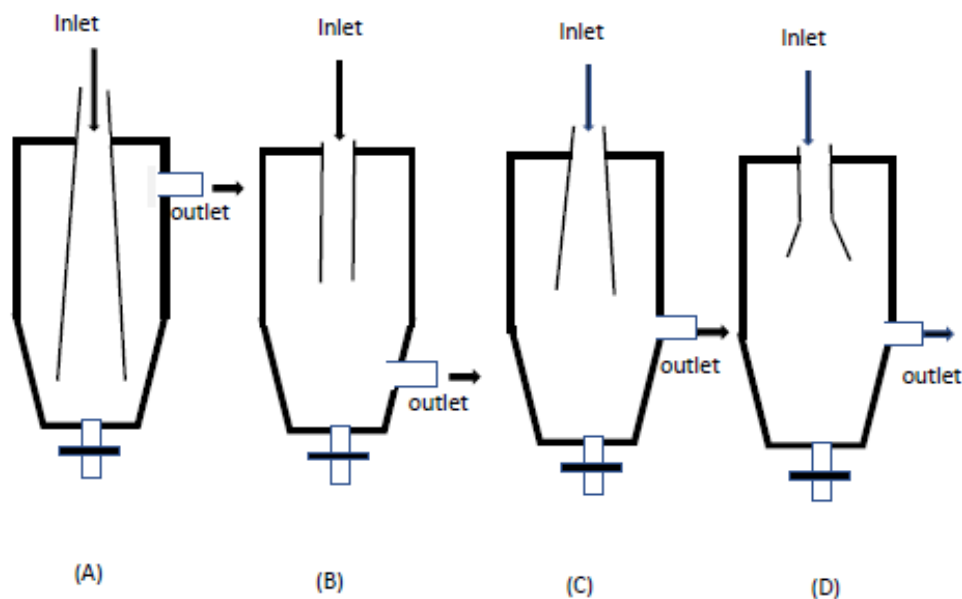
[BOF: Basic Oxygen Furnace; LF: Ladle Furnace; VD: Vacuum Degassing; CC: Continuous Casting].

- (A) BOF $\rightarrow$ LF $\rightarrow$ VD $\rightarrow$ CC
- (B) CC $\rightarrow$ BOF $\rightarrow$ LF $\rightarrow$ VD
- (C) VD $\rightarrow$ CC $\rightarrow$ BOF $\rightarrow$ LF
- (D) LF $\rightarrow$ BOF $\rightarrow$ VD $\rightarrow$ CC

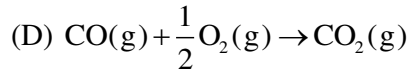
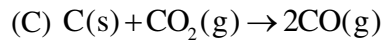
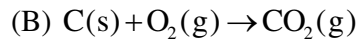
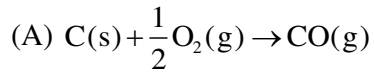
Q.10 The common ore of titanium is _____.

- (A) Bauxite
- (B) Chalcopryite
- (C) Cassiterite
- (D) Ilmenite

Q.11 Coarse suspended particles are to be separated from a flowing gas in a dust catcher. All factors remaining same, maximum gas-solid separation is expected from the dust catcher _____ shown below.



Q.12 The Boudouard (or, carbon gasification) reaction is _____.



Q.13 The fastest diffusing element in iron at 1100 °C is _____.

(A) Ni

(B) Co

(C) Cr

(D) C

Q.14 Hydrogen bonds are stronger than _____.

(A) Ionic bonds

(B) Metallic bonds

(C) van der Waals bonds

(D) Covalent bonds

Q.15 The carbide that is primarily responsible for intergranular corrosion in austenitic stainless steel is _____.

(A) $Cr_{23}C_6$

(B) Fe_3C

(C) SiC

(D) Mn_3C

Q.16 During low strain rate (≤ 0.1 per second) deformation of a metal at room temperature, the one that deforms by twinning mode is _____.

(A) Fe

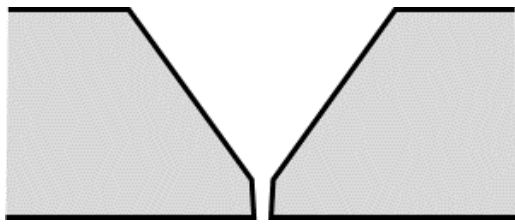
(B) Mg

(C) Al

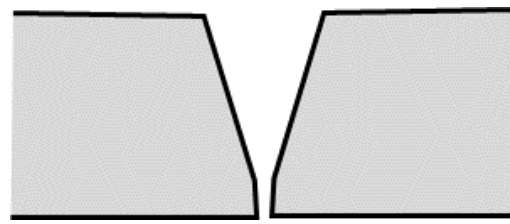
(D) Ni

- Q.17 In a tensile creep test of a metal, Nabarro-Herring mechanism is favored over Coble mechanism for _____.
- (A) larger grain size and lower temperature
(B) smaller grain size and higher temperature
(C) larger grain size and higher temperature
(D) smaller grain size and lower temperature
- Q.18 Beach marks are commonly observed on the fractured surfaces of metals after a _____.
- (A) Creep test
(B) Fatigue test
(C) Impact test
(D) Compression test
- Q.19 The length of internal cracks in two samples of the same glass is measured to be $C_1 = 0.5$ mm and $C_2 = 2$ mm. The ratio $\left(\frac{\sigma_1}{\sigma_2}\right)$ of the fracture strength of the two samples is _____.
- (A) 0.5 (B) 1.0 (C) 2.0 (D) 4.0

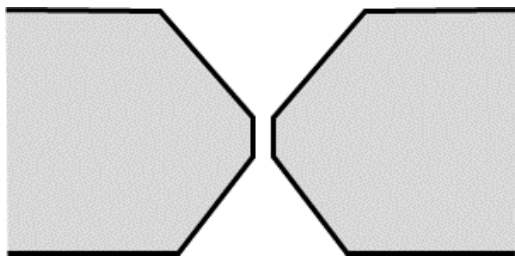
Q.20 Two blocks of the same metal are to be welded. The configuration that will undergo the least distortion after welding is _____.



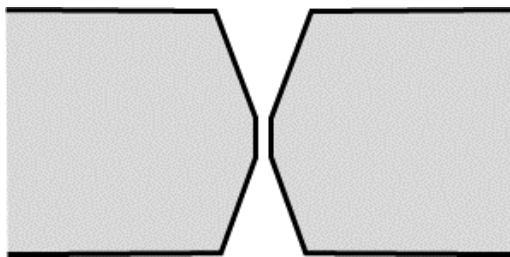
(A)



(B)



(C)



(D)

Q.21 The most suitable non-destructive testing method for detecting small internal flaws in a dense bulk material is _____.

(A) Dye penetrant method

(B) Ultrasonic inspection

(C) Eddy current testing

(D) Magnetic particle inspection

Q.22 Alligatoring is a defect commonly observed in _____.

(A) Extrusion

(B) Deep drawing

(C) Sheet metal forming

(D) Rolling

Q.23 The standard deviation (rounded off to one decimal place) of the following set of five numbers is _____.

6, 8, 8, 9, 9

Q.24 A FCC crystal with a lattice parameter of 0.3615 nm is used to measure the wavelength of monochromatic X-rays. The Bragg angle (θ) for the reflection from (111) planes is 21.68° . The wavelength of X-rays (in nm, rounded off to three decimal places) is _____.

Q.25 A plate of width 100 cm and thickness 5 cm is rolled to a thickness of 3 cm. If the entry velocity is 10 cm.s^{-1} , the exit velocity of the plate (in cm.s^{-1} , rounded off to one decimal place) is _____.

Assume no change in the width of the plate.

Q. 26 – Q. 55 carry two marks each.

Q.26 Match the reactors / refining sites in **Column I** with the corresponding refining processes in **Column II**.

Column I: Reactors / refining sites

(P) Blast furnace runner

(Q) AOD

(R) Torpedo car

(S) BOF

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

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

Column II: Refining processes

1. De-carburization

2. External De-sulfurization

3. De-phosphorization

4. External De-siliconization

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

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

Q.27 Match the injection metallurgy techniques in **Column I** with the corresponding objectives in **Column II**.

Column I: Injection metallurgy techniques

(P) Aluminium wire feeding

(Q) Calcium treatment

(R) Argon rinsing

(S) Lime powder injection

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

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

Column II: Objectives

1. Inclusion modification

2. Mixing of liquid steel

3. De-sulphurization

4. Deoxidation

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

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

Q.28 The table (see options below) providing correct information about crystal structure, coordination number and packing fraction is _____.

[Note: FCC: Face centered cubic; BCC: Body centered cubic; DC: Diamond cubic.

CN: Coordination number; PF: Packing fraction]

(A)

Crystal structure	CN	PF
FCC	12	0.74
BCC	8	0.68
DC	4	0.34

(B)

Crystal structure	CN	PF
FCC	8	0.74
BCC	4	0.68
DC	6	0.34

(C)

Crystal structure	CN	PF
FCC	8	0.52
BCC	12	0.68
DC	12	0.74

(D)

Crystal structure	CN	PF
FCC	12	0.74
BCC	8	0.68
DC	4	0.74

Q.29 Match the phase transformation in **Column I** with the corresponding reaction in

Column II.

[Note: α , β , γ are solid phases; L, L_1 , L_2 are liquid phases.]

Column I: Phase transformation

Column II: Reaction

(P) Peritectic

1. $\gamma \rightarrow \alpha + \beta$

(Q) Monotectic

2. $L_1 + L_2 \rightarrow \alpha$

(R) Eutectoid

3. $L_1 \rightarrow L_2 + \alpha$

(S) Syntectic

4. $L + \alpha \rightarrow \beta$

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

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

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

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

Q.30 In a typical scanning electron microscope (SEM) image, information about topography and atomic contrast are obtained from _____.

- (A) secondary electron and auger electron, respectively.
- (B) primary electron and secondary electron, respectively.
- (C) secondary electron and back-scatter electron, respectively.
- (D) back-scatter electron and auger electron, respectively.

Q.31 Match the ceramics in **Column I** with corresponding application in **Column II**.

Column I: Ceramics**Column II: Application**

- | | |
|----------------------|------------------|
| (P) Mullite | 1. Cutting tools |
| (Q) Spinel ferrites | 2. Refractories |
| (R) Tungsten carbide | 3. Piezoelectric |
| (S) Barium titanate | 4. Soft magnet |

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

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

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

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

Q.32 An aluminium single crystal is loaded in tension along $[1\bar{1}0]$ axis. Among the following slip systems, the one that will be activated first is_____.

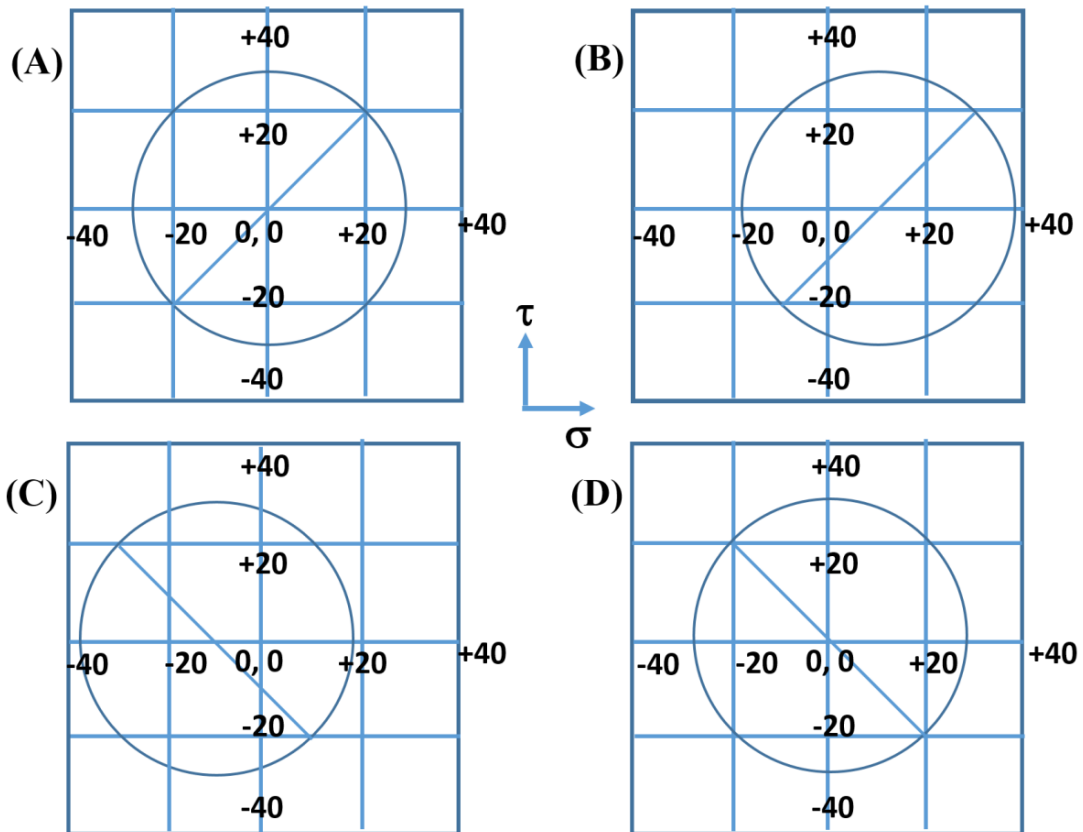
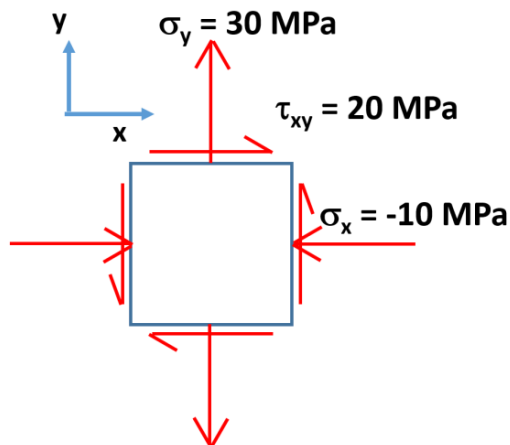
(A) $(1\bar{1}\bar{1})[0\bar{1}1]$

(B) $(\bar{1}\bar{1}1)[011]$

(C) $(\bar{1}\bar{1}1)[1\bar{1}0]$

(D) $(\bar{1}\bar{1}1)[101]$

Q.33 The correct Mohr's circle construction for the stress state given below is _____.



Q.34 Match the automobile components in **Column I** with the corresponding manufacturing processes in **Column II**.

Column I: Automobile components

Column II: Manufacturing process

(P) Engine block

1. Forging

(Q) Brake pad

2. Sheet metal forming

(R) Connecting rod

3. Casting

(S) Door panel

4. Powder metallurgy

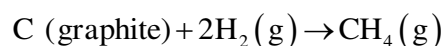
(A) P-1, Q-2, R-3, S-4

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

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

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

Q.35 The equilibrium constant for the following reaction at 300 K is _____.



Given: At 300 K, $\Delta H^\circ = -74,900 \text{ J.mol}^{-1}$; $\Delta S^\circ = -80 \text{ J.mol}^{-1}.\text{K}^{-1}$;

$R = 8.314 \text{ J.mol}^{-1}.\text{K}^{-1}$.

(A) 5.6×10^6

(B) 3.6×10^7

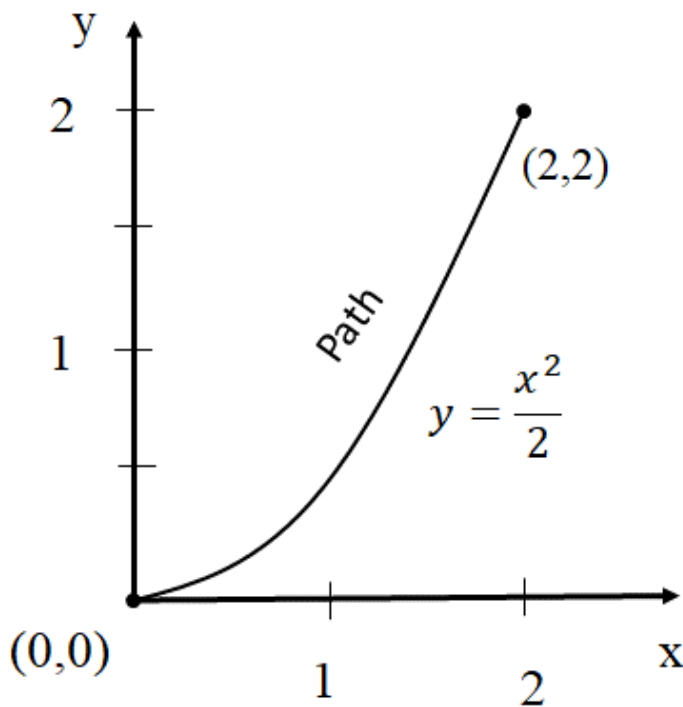
(C) 4.0×10^8

(D) 7.3×10^8

Q.36 A 50 cm long rod is placed against a vertical wall such that the bottom of the rod is 30 cm away from the wall. If the bottom of the rod is pulled horizontally away from the wall at 4 cm.s^{-1} , the top of the rod starts sliding down the wall with an instantaneous velocity (in cm.s^{-1} , rounded off to two decimal places) of magnitude _____.

Q.37 The probability of solving a problem by Student A is $(1/3)$, and the probability of solving the same problem by Student B is $(2/5)$. The probability (rounded off to two decimal places) that at least one of the students solves the problem is _____.

Q.38 Numerical value of work done (rounded off to the nearest integer) by a position-dependent force $\vec{F} = x\hat{i} + 5xy\hat{j}$ (where $\hat{i}$ and $\hat{j}$ are unit vectors) along the path, $y = \frac{x^2}{2}$, from $(0,0)$ to $(2,2)$ in the xy plane is _____.



Q.39 The estimated value of the cube root of 37 (rounded off to two decimal places) obtained from the Newton-Raphson method after **two** iterations (x_2) is _____.
 [Start with an initial guess value of $x_0 = 1$].

Q.40 The partial pressure of zinc (in **torr**, rounded off to two decimal places) in equilibrium with liquid lead containing 0.03 mole % zinc at 900 K is _____.

Given: Vapour pressure of pure zinc (p_{Zn}°) at 900 K is 0.027 atm. Henry's law coefficient (γ_{Zn}°) for zinc at infinite dilute solution in lead on Raoultian scale is 8.55.

$$1 \text{ torr} = 1.316 \times 10^{-3} \text{ atm.}$$

Q.41 Steady state radial heat conduction through a hollow, infinitely long zirconia cylinder is governed by the following ordinary differential equation:

$$\frac{1}{r} \frac{d}{dr} \left(r k \frac{dT}{dr} \right) = 0$$

Where, T is the temperature and r is the radial distance. The inner surface of the hollow cylinder is maintained at 1473 K and the outer surface at 973 K. The rate of heat loss per unit length through the outer surface of the hollow cylinder (in $W.m^{-1}$, rounded off to the nearest integer) is _____.

Given: Inner radius of cylinder = 0.05 m; outer radius of cylinder = 0.07 m and thermal conductivity of zirconia (k) = $2 W.m^{-1}.K^{-1}$.

Q.42 A 50 mm (diameter) sphere of solid nickel is oxidized in a gas mixture containing 60% argon and 40% oxygen by volume. The rate of oxidation of nickel is controlled by the rate of transport of oxygen through the concentration boundary layer. The rate of oxidation (**in moles of nickel per minute (mol/min)**), rounded off to two decimal places) is _____.

Given: Total pressure = 1 atm.; Temperature = 1173 K; Concentration of oxygen at the surface of the solid = 0; Boundary layer mass transfer coefficient = 0.03 m.s^{-1} ; Universal gas constant, $R = 8.205 \times 10^{-5} \text{ m}^3 \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$. Assume ideal gas behavior.

Q.43 Equilibrium concentration of dissolved nitrogen (in wt.%, rounded off to **three** decimal places) in pure liquid iron, exposed to atmospheric air at 1873 K, is _____.

Given: Sieverts' law constant as a function of temperature (T; in Kelvin) is

$$\log_{10} K_{[N]} = \left[-\frac{518}{T} - 1.063 \right], \text{ where } K_{[N]} \text{ has the dimension of } \text{atm}^{-(1/2)}.$$

Assume $[h_N] = [\text{wt.\% N}]$, where $[h_N]$ is the activity of nitrogen with respect to 1 wt.% Henrian standard state.

Q.44 Pressure drop in the granular zone of a blast furnace is 300 mm of water per meter of the bed height. The bed permeability is $0.8 \text{ m}^4 \cdot \text{N}^{-1} \cdot \text{s}^{-1}$. The volumetric flow rate of gas per unit area through the bed [in $(\text{m}^3 \cdot \text{s}^{-1}) \cdot \text{m}^{-2}$, rounded off to the nearest integer] is _____.

Assume Darcy's law is applicable and $g = 9.8 \text{ m.s}^{-2}$. Density of water = 1000 kg.m^{-3} .

Q.45 A blast furnace charged with hematite containing 90 wt.% Fe_2O_3 produces liquid iron with 3.6 wt.% carbon. Coke containing 90 wt.% carbon is charged at a rate of 500 kg per Metric ton of liquid iron produced. The blast furnace top gas contains (by volume), 22% CO , 18% CO_2 , and balance nitrogen. The volume of the blast furnace top gas [in m^3 (NTP), rounded off to the nearest integer] is _____.

Given: Assume ideal gas behavior, and molar volume of the gas at NTP is 22.4 liter.

Q.46 100 Metric tons of copper concentrate containing 21 wt.% Cu is to be processed in 6 months with 25 working days per month and 8 working hours per day. The concentrate is leached by sulphuric acid and electrolyzed in 10 cells arranged in series. The minimum current rating (**Ampere per month per cell**, rounded off to the nearest integer) is _____.

Given: Faraday constant = 96500 *Coulomb per gram equivalent*.

Atomic weight of copper is 63.

Q.47 Cold working of iron leads to increase in dislocation density from 10^{10} to 10^{15} m^{-2} . The associated stored energy (in **$\text{MJ} \cdot \text{m}^{-3}$** , rounded off to one decimal place) is _____.

Given: Shear modulus of iron = 82 GPa, Burger's vector, $\vec{b} = \frac{a_0}{2} [111]$,

$a_0 = 0.2856 \text{ nm}$.

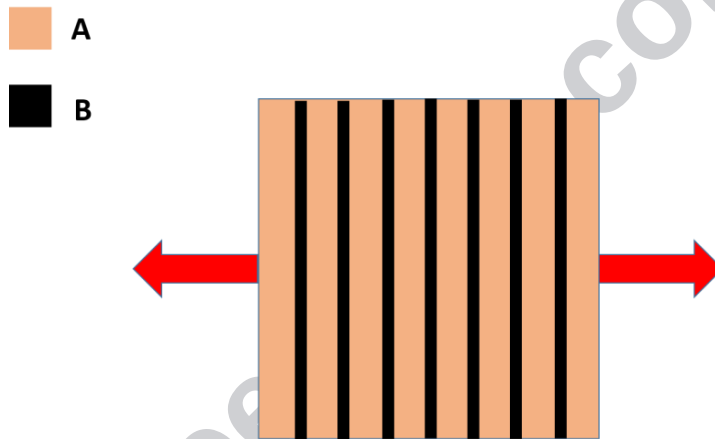
Q.48 The critical radius (in **nm**, rounded off to one decimal place) of nickel nucleus during solidification at 1673 K is _____.

Given: Enthalpy of fusion of nickel = $2.65 \times 10^9 \text{ J.m}^{-3}$;

Liquid-solid interfacial energy = 0.5 J.m^{-2} , and

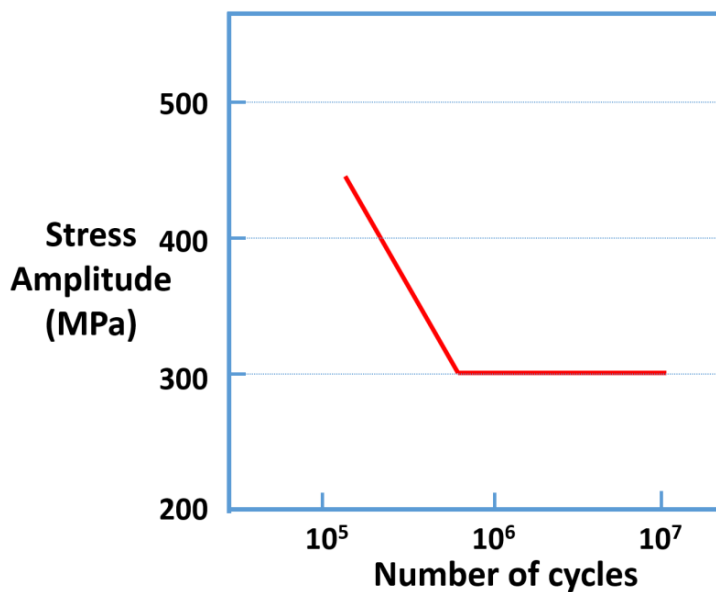
Equilibrium melting temperature of nickel = 1728 K.

Q.49 A material, made up of alternating layers of metals **A** and **B**, is loaded as shown below. If the volume % of **B** is 25%, the elastic modulus (in GPa, rounded off to one decimal place) of the material is _____.



Given: Elastic moduli of **A** and **B** are 200 GPa and 100 GPa, respectively.

- Q.50 The S-N curve for a steel is shown below. If the stress ratio, $(\sigma_{min}/\sigma_{max}) = -0.8$, the maximum stress (in MPa, rounded off to the nearest integer) that the steel can withstand for infinite fatigue life is _____.

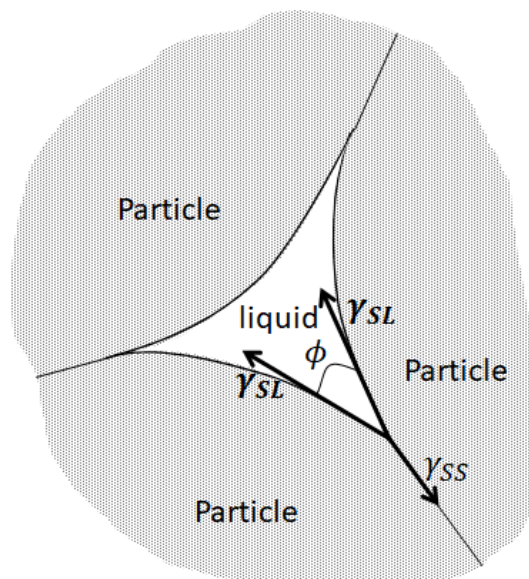


- Q.51 True stress - true strain behavior of a metal is given by the flow curve equation

$\sigma = 1750\epsilon^{0.37}$, where σ is in MPa. The true stress at necking (in MPa, rounded off to the nearest integer) is _____.

- Q.52 In sand-mold casting of a metal, it takes 180 seconds for complete solidification of a 27 cm^3 cube-shaped casting. All other parameters remaining constant, the total solidification time (in seconds, rounded off to one decimal place) for a cylinder-shaped [radius = 1 cm and height = 6 cm] casting of the same metal, is _____.

- Q.53 If the solid-solid interfacial energy (γ_{SS}) is $0.87 \text{ J} \cdot \text{m}^{-2}$ and solid-liquid interfacial energy (γ_{SL}) is $0.5 \text{ J} \cdot \text{m}^{-2}$, the dihedral angle (ϕ , in degree, rounded off to one decimal place) during sintering is _____.



- Q.54 The maximum possible reduction (in mm , rounded off to one decimal place) of a 100 mm thick slab during rolling is _____.

Given: The coefficient of friction between roll and the slab is 0.2, and the roll diameter is 200 mm.

- Q.55 An arc welding is performed at 400 Amperes, 20 V at a traverse speed of $5 \text{ mm} \cdot \text{s}^{-1}$. If the heat transfer efficiency is 0.6, the energy input per unit length (in $\text{J} \cdot \text{mm}^{-1}$, rounded off to the nearest integer) during the process is _____.

END OF THE QUESTION PAPER