MT : METALLURGICAL ENGINEERING

Duration: Three Hours *Maximum Marks*: 100

Read the following instructions carefully.

1. This question paper contains **16** pages including blank pages for rough work. Please check all pages and report discrepancy, if any.

2. Write your registration number, your name and name of the examination centre at the specified locations on the right half of the Optical Response Sheet (**ORS**).

3. Using HB pencil, darken the appropriate bubble under each digit of your registration number and the letters corresponding to your paper code.

4. All questions in this paper are of objective type.

5. Questions must be answered on the **ORS** by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number on the left hand side of the ORS. **For each question darken the bubble of the correct answer.** In case you wish to change an answer, erase the old answer completely. More than one answer bubbled against a question will be treated as an incorrect response.

6. There are a total of 65 questions carrying 100 marks.

7. Questions Q.1 – Q.25 will carry 1-mark each, and questions Q.26 – Q.55 will carry 2-marks each.

8. Questions Q.48 – Q.51 (2 pairs) are common data questions and question pairs (Q.52, Q.53) and (Q.54, Q.55) are linked answer questions. The answer to the second question of the linked answer questions depends on the answer to the first question of the pair. If the first question in the linked pair is wrongly answered or is un-attempted, then the answer to the second question in the pair will not be evaluated.

9. Questions Q.56 – Q.65 belong to General Aptitude (GA). Questions Q.56 – Q.60 will carry 1-mark each, and questions Q.61 – Q.65 will carry 2-marks each. The GA questions will begin on a fresh page starting from page **9**.

10. Un-attempted questions will carry zero marks.

11. Wrong answers will carry **NEGATIVE** marks. For Q.1 – Q.25 and Q.56 – Q.60, ⅓ mark will be deducted for each wrong answer. For Q.26 – Q.51 and Q.61 – Q.65, ⅔ mark will be deducted for each wrong answer. The question pairs (Q.52, Q.53), and (Q.54, Q.55) are questions with linked answers. There will be negative marks only for wrong answer to the first question of the linked answer question pair i.e. for Q.52 and Q.54, ⅔ mark will be deducted for each wrong answer. There is no negative marking for Q.53 and Q.55.

12. Calculator (without data connectivity) is allowed in the examination hall.

13. Charts, graph sheets or tables are NOT allowed in the examination hall.

14. Rough work can be done on the question paper itself. Additionally, blank pages are provided at the end of the question paper for rough work.

SEAL

Useful Data

Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}$ W m^{-2}K^{-4}
Gas constant, $R = 8.314$ J mol^{-1} K^{-1}
Electron charge, $e = 1.6 \times 10^{-19}$ C
Faraday's constant, $F = 96500$ C mol^{-1}
Avogadro's number, $N = 6.023 \times 10^{23}$ mol^{-1}

Q.1 – Q.25 carry one mark each.

Q.1 Which of the following is NOT a property of a n × n singular matrix?

(A) Rank = n
(B) Linearly dependent row vectors
(C) Zero diagonal in Gauss elimination
(D) Linearly dependent column vectors

Q.2 Which of the following is an iterative technique to solve a linear system of equations?

(A) Gaussian elimination
(B) LU decomposition
(C) Newton-Raphson
(D) Jacobi method

Q.3 Given the data set {27.90, 34.70, 64.40, 18.92, 47.60, 39.68} Median value for the data set is

(A) 36.9 (B) 37.19 (C) 38.86 (D) 54.4

Q.4 Which of the following is typical form of a wave equation?

(A) $x^2\frac{d^2u}{dx^2}+x\frac{du}{dx}+u=0$
(B) $\nabla^2 u = a\frac{\partial^2 u}{\partial t^2};\ a>0$
(C) $\nabla^2 u = 0$
(D) $\nabla^2 u = a\frac{\partial u}{\partial t};\ a>0$

Q.5 A vector makes angles α, β and γ with the three axes x, y and z, respectively. The value of $\cos^2\alpha+\cos^2\beta+\cos^2\gamma$ is

(A) −1 (B) 0 (C) 1 (D) not determinable

Q.6 Which of the following is NOT a solid state welding process?

(A) Friction stir welding
(B) Ultrasonic welding
(C) Explosive welding
(D) Flux cored arc welding

Q.7 In a homogeneous system (with c as the number of components) in equilibrium the total number of independent intensive thermodynamic variables is

(A) $c-1$ (B) c (C) $c+1$ (D) $c+2$

Q.8 Which of these metals CANNOT be electroplated from aqueous electrolyte?

(A) Al (B) Cu (C) Ni (D) Zn

Q.9 At steady state and when the inner and outer walls of a long hollow cylinder are kept at two different temperatures, the unidirectional temperature variation along the thickness of the wall is

(A) linear (B) parabolic (C) logarithmic (D) constant

Q.10 In a basic oxygen furnace, under appropriate conditions, which of the following statements is NOT correct?

(A) Carbon can be removed in preference to P and S
(B) Phosphorus can be removed in preference to C and S
(C) Sulphur can be removed in preference to C and P
(D) Carbon and phosphorus can be removed in preference to S

Q.11 The miller indices of the direction common to the planes (111) and (110) in a cubic system is

(A) [111] (B) [110] (C) $[\bar{1}10]$ (D) $[\bar{1}\bar{1}1]$

Q.12 In continuous casting of steel, the mould is subjected to vertical oscillations in order to

(A) allow easy flotation of inclusions
(B) ensure good casting homogeneity
(C) increase the heat transfer rate from the steel to the mould
(D) prevent the skin sticking to the mould

Q.13 The engineering stress-strain curve for a ceramic material is

(A) parabolic (B) exponential (C) logarithmic (D) linear

Q.14 Which of the following statements regarding Kroll's process is NOT correct?

(A) Pure metal chlorides serve as main raw material
(B) Reduction is done only by sodium
(C) Reduction chamber should be free of oxygen
(D) It is used for extraction of titanium and zirconium

Q.15 The energy dispersive spectrometer (EDS) in an electron microscope does chemical analysis by analysing the energy of

(A) secondary electrons (B) characteristic X-rays
(C) auger electrons (D) back-scattered electrons

Q.16 In heterogeneous nucleation, the radius of the critical nucleus does NOT depend on

(A) contact angle
(B) undercooling
(C) the surface energy of the interface between the product and parent phases
(D) enthalpy change per unit volume of the product phase

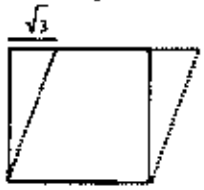
Q.17 The third peak in the X-ray diffraction pattern of a polycrystalline BCC metal is

(A) (111) (B) (110) (C) (211) (D) (220)

Q.18 Number of slip systems in an ideal close packed hexagonal structure is

(A) 3 (B) 12 (C) 24 (D) 48

Q.19 A square of 9 mm^2 area is subjected to simple shear displacement $\sqrt{3}$ mm along x-direction, as shown below



The shear strain imparted will be

(A) 1/3 (B) $1/\sqrt{3}$ (C) $\sqrt{3}$ (D) 3

Q.20 During metal casting of a slab, the thickness of solid formed after time t is proportional to

(A) $t^{1/3}$ (B) $t^{1/2}$ (C) t (D) t^2

Q.21 Which of the following is a suitable method to remove hydrogen from molten aluminium?

(A) Expose flowing melt to vacuum
(B) Bubble humidified argon gas through the melt
(C) Increase melt temperature
(D) Cover melt surface with a flux

Q.22 Driving force for grain growth after completion of recrystallization is

(A) stored energy of cold work (B) vacancy concentration
(C) dislocation density in the crystal (D) grain boundary curvature

Q.23 Which of the following partial derivative is equal to $\left(\frac{\partial S}{\partial P}\right)_T$

(A) $-\left(\frac{\partial V}{\partial T}\right)_P$ (B) $\left(\frac{\partial S}{\partial V}\right)_T$ (C) $\left(\frac{\partial V}{\partial T}\right)_S$ (D) $-\left(\frac{\partial S}{\partial V}\right)_T$

Q.24 Which of the following are NOT commercially manufactured by powder metallurgy

(A) aircraft brake pads (B) self lubricating bearings
(C) tungsten carbide based cutting tools (D) turbine blades

Q.25 Two fluids of densities ρ_1 and ρ_2 are flowing at velocities v_1 and v_2, respectively, through smooth pipes of identical diameter and pressure per unit length. When the friction factor is same, the ratio ρ_1/ρ_2 is equal to

(A) v_1/v_2 (B) $(v_1/v_2)^2$ (C) $(v_2/v_1)^2$ (D) $(v_2/v_1)^{1/2}$

Q.26 – Q.55 carry two marks each.

Q.26 Determine the radius (in m) of a cylinder of volume 200 m^3 that has the least surface area

(A) 2.302 (B) 3.142 (C) 3.169 (D) 7.233

Q.27 Given the polynomial $x^3 - 3x^2 + 4x - 2.5 = 0$
Starting from a guess value $x = 0$ what will be the value of x after iterating twice using the Newton-Raphson method.

(A) 0.625 (B) 1.278 (C) 1.441 (D) 1.562

Q.28 The probability of obtaining "head" n times, on tossing an unbiased coin N times, is given by

(A) ${}^NC_n\left(\frac{1}{2}\right)^N$ (B) $\frac{n}{N}$ (C) $\left(\frac{1}{2}\right)^N$ (D) ${}^NP_n\left(\frac{1}{2}\right)^N$

Q.29 The $\lim_{x\to 0}\frac{\sin^2 ax}{\sin^2 x}$ is

(A) a^2 (B) 0 (C) 1 (D) undefined

Q.30 Solution of the equation $2x\frac{dy}{dx}+3y=0$ is

(A) $x^{3/2}$ (B) $x^{-3/2}$ (C) $x^{-1/2}$ (D) $x^{1/2}$

Q.31 Match the metallurgical processes in **Group I** with their corresponding reactors types in **Group II**.

Group I	**Group II**
P. Roasting of sulphide concentrate	1. Pneumatic reactor
Q. LD steel making	2. Retort
R. Dwight-Lloyd sintering	3. Travelling grate reactor
S. Zinc extraction	4. Fluidized bed reactor

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

Q.32 The theoretical density of an FCC metal with atomic radius and atomic weight of 0.144 nm and 197 g mol^{-1}, respectively, is approximately (in kg m^{-3})

(A) 18110 (B) 18300 (C) 19360 (D) 19890

Q.33 In a binary system, the difference in chemical potentials of two components ($\mu_i-\mu_j$) is equal to

(A) $\frac{dG_m}{dx_j}$ (B) 0 (C) $(1-x_j)\frac{dG_m}{dx_j}$ (D) $-\frac{dG_m}{dx_j}$

Q.34 The temperature of a gas flowing in a long duct as measured by a thermocouple (having an emissivity of 0.5) is 800 K. The internal wall surface of the duct is at a temperature of 500 K. The convective heat transfer coefficient between the gas and the tip of the thermocouple is 100 $Wm^{-2}K^{-1}$. The actual gas temperature is approximately

(A) 400 K (B) 500 K (C) 820 K (D) 900 K

Q.35 A recrystallization process is 20% complete after 45 s and 85% complete after 75 s. Assuming Avrami kinetics, the value of Avrami exponent "n" is

(A) 4.19 (B) 3.12 (C) 2.42 (D) 1.34

Q.36 Match the defects given in **Group I** with the suitable non-destructive evaluation technique from **Group II**.

Group I	**Group II**
P. Cracks in a flat aluminium slab	1. Radiography
Q. Subsurface porosity in a bronze casting	2. Eddy current technique
R. Surface cracks in a steel tool	3. Ultrasonic technique
S. Internal porosity in a ceramic block	4. Magnetic particle technique

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

Q.37 Silicon is doped with arsenic (concentration 10^{20} atoms m^{-3}). At room temperature, the electron and hole mobilities in Si are 0.14 $m^2 V^{-1}s^{-1}$ and 0.05 $m^2 V^{-1}s^{-1}$, respectively. The conductivity, in $(\Omega m)^{-1}$, at room temperature for Si doped with As is

(A) 0.11 (B) 0.96 (C) 2.24 (D) 2.72

Q.38 Four eutectoid steel samples W, X, Y and Z are austenetized and then subjected to normalizing, quenching, martempering and austempering treatments, respectively. Which of the following statements is NOT correct?

(A) The microstructure of sample W will be fully pearlitic
(B) The microstructure of sample X will be untempered martensite
(C) The microstructure of sample Y will be tempered martensite
(D) The microstructure of sample Z will be bainitic

Q.39 The difference in reversible potential between oxygen reduction reaction and hydrogen evolution reaction at any pH in an aqueous electrolyte is
(given standard reduction potentials for hydrogen evolution reaction: $E^{0}_{2H^{+}/H_2} = 0$ V, SHE and oxygen reduction reaction: $E^{0}_{O_2/4OH^{-}} = 0.4$ V, SHE. Also, $p_{H_2} = p_{O_2} = 1$ atm)

(A) 0 V (B) 0.41 V (C) 0.82 V (D) 1.23 V

Q.40 Assertion **a**: Hardenability of steel can be increased by adding certain alloying elements.
Reason **r**: The alloying elements can provide a fine dispersion of alloy carbides.

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

Q.41 Consider the following collection of polymer chains:

Number of molecules	10	5	4	2	1
Molecular weight (g mol^{-1})	2800	3000	1200	3600	1000

Mer unit is ethylene. Atomic weights: carbon (12) and hydrogen (1). Calculate number average degree of polymerization.

(A) 32.32 (B) 90.91 (C) 106.61 (D) 116.13

Q.42 At 910°C, γ-Fe transforms to α-Fe resulting in a percentage volume expansion of

(A) 5.6 (B) 7.1 (C) 7.6 (D) 8.8

Q.43 **Group I** is a list of technologies for alternate methods of producing iron. **Group II** is a list of terms you come across in the context of these technologies. Match the items.

Group I	**Group II**
P. MIDREX	1. Retort
Q. COREX	2. Rotary kiln
R. SL/RN	3. Smelting reduction
S. Hyl-I	4. Shaft furnace

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

Q.44 If the true stress–true strain curve of a ductile material is represented by the equation $\sigma = 1100\,\varepsilon^{0.20}$, the ultimate tensile strength (engineering) will be

(A) 853 MPa (B) 753 MPa (C) 653 MPa (D) 553 MPa

Q.45 The maximum possible reduction in a single pass for cold rolling of a 200 mm slab is (given the coefficient of friction is 0.1 and roll diameter is 400 mm)

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

Q.46 Match the requirement from **Group I** with the suitable casting process from **Group II**.

Group I	**Group II**
P. Good surface finish	1. Slush casting
Q. Expendable mould	2. Pressure die casting
R. Heavy casting	3. Investment casting
S. Hollow ornamental casting	4. Sand casting

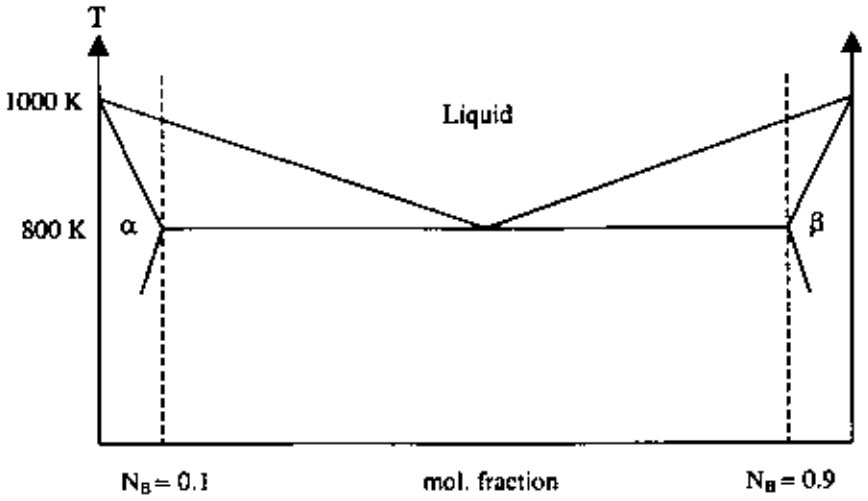
(A) P-2, Q-3, R-4, S-1 (B) P-4, Q-2, R-4, S-1
(C) P-4, Q-3, R-1, S-4 (D) P-2, Q-1, R-3, S-4

Q.47 The tensile test of a sheet material exhibits 20% elongation in length and 10% decrease in width. The plastic strain ratio is

(A) 2.37 (B) 1.37 (C) 1.17 (D) 0.87

Common Data Questions

Common Data for Questions 48 and 49



In the above hypothetical phase diagram, the melting point of each pure component is 1000 K and the eutectic temperature is 800 K. The eutectic is located at the equi-atomic composition. The maximum solid solubility in α phase is given by mole fraction $N_B = 0.1$.

Q.48 The freezing range (in K) of the alloy with composition $N_B = 0.1$ is
(A) 100 (B) 130 (C) 160 (D) 190

Q.49 On cooling an alloy of composition $N_B = 0.2$, the fraction of pro-eutectic α phase at the eutectic temperature is

(A) 0.75 (B) 0.65 (C) 0.55 (D) 0.45

Common Data for Questions 50 and 51

An aluminium alloy rod of diameter 15 mm and length 120 mm is subjected to a tensile load of 35,000 N along its axis. The Young's modulus and Poisson's ratio for aluminium are 70 GPa and 0.33 respectively.

Q.50 The reduction in diameter on the application of tensile load is
(A) 0.011 mm (B) 0.014 mm (C) 0.018 mm (D) 0.021 mm

Q.51 The elastic strain energy is approximately

(A) 200 kJ m^{-3} (B) 240 kJ m^{-3} (C) 280 kJ m^{-3} (D) 320 kJ m^{-3}

Linked Answer Questions

Statement for Linked Answer Questions 52 and 53

At 1200°C the standard Gibbs energy of thermal decomposition of one mole of wüstite into Fe and O_2 is 168 kJ.

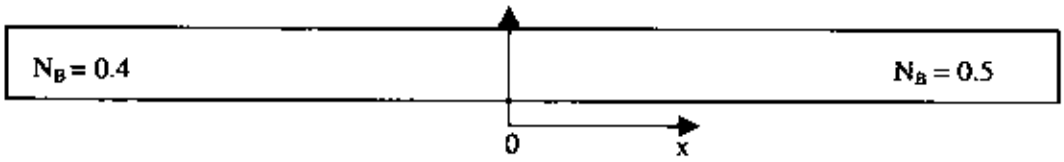
Q.52 The corresponding dissociation pressure (in atm) is

(A) 2.51×10^{-15} (B) 1.22×10^{-12} (C) 5.00×10^{-8} (D) 1.13×10^{-6}

Q.53 Given for the reaction $2CO + O_2 \leftrightarrow 2CO_2$ the standard Gibbs energy is −310 kJ, what is the equivalent $\left(\frac{p_{CO}}{p_{CO_2}}\right)$

(A) 0.03 (B) 1.01 (C) 1.85 (D) 2.89

Statement for Linked Answer Questions 54 and 55



The diffusion couple shown above is made from two A-B alloys. The initial compositions of the two alloys are indicated in the diagram. The centreline is at $x = 0$. The couple is held at an elevated temperature for 40 hours. Diffusivity $D = 3 \times 10^{-11}$ $m^2 s^{-1}$. Assume the diffusion couple to be infinitely long.

Q.54 Which of the parameters give the composition profile in the following form?

$$C(x,t) = C_1 + C_2 erf\left(\frac{x}{2\sqrt{Dt}}\right)$$

(A) $C_1 = 0.45$, $C_2 = 0.05$ (B) $C_1 = 0.5$, $C_2 = 0.4$
(C) $C_1 = -0.05$, $C_2 = 0.45$ (D) $C_1 = 0.1$, $C_2 = 0.9$

Q.55 The composition at a distance $x = 2$ mm is approximately (assuming $erf(x) \approx x$ for small x)

(A) 0.3 (B) 0.474 (C) 0.524 (D) 0.7

General Aptitude (GA) Questions

Q.56 – Q.60 carry one mark each.

Q.56 *Which of the following options is the closest in meaning to the word below:*
Circuitous

(A) cyclic
(B) indirect
(C) confusing
(D) crooked

Q.57 *The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair.*
Unemployed : Worker

(A) fallow : land
(B) unaware : sleeper
(C) wit : jester
(D) renovated : house

Q.58 *Choose the most appropriate word from the options given below to complete the following sentence:*
If we manage to _____ our natural resources, we would leave a better planet for our children.

(A) uphold
(B) restrain
(C) cherish
(D) conserve

Q.59 *Choose the most appropriate word from the options given below to complete the following sentence:*
His rather casual remarks on politics _____ his lack of seriousness about the subject.

(A) masked
(B) belied
(C) betrayed
(D) suppressed

Q.60 25 persons are in a room. 15 of them play hockey, 17 of them play football and 10 of them play both hockey and football. Then the number of persons playing neither hockey nor football is:

(A) 2 (B) 17 (C) 13 (D) 3

Q.61 – Q.65 carry two marks each.

Q.61 **Modern warfare has changed from large scale clashes of armies to suppression of civilian populations. Chemical agents that do their work silently appear to be suited to such warfare; and regretfully, there exist people in military establishments who think that chemical agents are useful tools for their cause.**

Which of the following statements best sums up the meaning of the above passage:

(A) Modern warfare has resulted in civil strife.
(B) Chemical agents are useful in modern warfare.
(C) Use of chemical agents in warfare would be undesirable.
(D) People in military establishments like to use chemical agents in war.

Q.62 If 137 + 276 = 435 how much is 731 + 672?

(A) 534 (B) 1403 (C) 1623 (D) 1513

Q.63 5 skilled workers can build a wall in 20 days; 8 semi-skilled workers can build a wall in 25 days; 10 unskilled workers can build a wall in 30 days. If a team has 2 skilled, 6 semi-skilled and 5 unskilled workers, how long will it take to build the wall?

(A) 20 days (B) 18 days (C) 16 days (D) 15 days

Q.64 Given digits 2, 2, 3, 3, 3, 4, 4, 4, 4 how many distinct 4 digit numbers greater than 3000 can be formed?

(A) 50 (B) 51 (C) 52 (D) 54

Q.65 Hari (H), Gita (G), Irfan (I) and Saira (S) are siblings (i.e. brothers and sisters). All were born on 1st January. The age difference between any two successive siblings (that is born one after another) is less than 3 years. Given the following facts:

i. Hari's age + Gita's age > Irfan's age + Saira's age.
ii. The age difference between Gita and Saira is 1 year. However, Gita is not the oldest and Saira is not the youngest.
iii. There are no twins.

In what order were they born (oldest first)?

(A) HSIG (B) SGHI (C) IGSH (D) IHSG

END OF THE QUESTION PAPER

Space for Rough Work

Space for Rough Work

Space for Rough Work

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SEAL