MT : METALLURGICAL ENGINEERING

Duration : Three Hours *Maximum Ma*

Read the following instructions carefully.

1. This question paper contains **16** printed pages including 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 **O**ptical **R**esponse **S**heet (**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 **O**ptical **R**esponse **S**heet (**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. **Each question has only one 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 60 questions carrying 100 marks. Questions 1 through 20 are 1-mark questions, questions 21 through 60 are 2-mark questions.

7. Questions 51 through 56 (3 pairs) are common data questions and question pairs (57, 58) and (59, 60) are linked answer questions. The answer to the second question of the above 2 pairs 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.

8. Un-attempted questions will carry zero marks.

9. Wrong answers will carry NEGATIVE marks. For Q.1 to Q.20, ⅓ mark will be deducted for each wrong answer. For Q. 21 to Q. 56, ⅔ mark will be deducted for each wrong answer. The question pairs (Q.57, Q.58), and (Q.59, Q.60) 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.57 and Q.59, ⅔ mark will be deducted for each wrong answer. There is no negative marking for Q.58 and Q.60.

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

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

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

Useful Data

Gas constant = 8.314 J mol^{-1} K^{-1}
Faraday constant = 96500 C / mol
Atomic weights: H = 1, C = 12, Fe = 56, N = 14, O = 16

Q. 1 – Q. 20 carry one mark each.

Q.1 In an $n \times n$ identity matrix, the trace equals

(A) 0 (B) 1 (C) n (D) n^2

Q.2 Gibbs free energies of a system in states 1 and 2 are denoted by G_1 and G_2 respectively. The system will go spontaneously from state 1 to state 2, if and only if

(A) $G_1 - G_2 > 0$ (B) $G_1 - G_2 < 0$
(C) $G_1 - G_2 = 0$ (D) $G_1 < 0$ and $G_2 < 0$

Q.3 Flux in welding process acts as

(A) catalyst (B) protective agent (C) filler (D) heat generator

Q.4 In an ideal HCP packing, the c/a ratio is

(A) 1.225 (B) 1.414 (C) 1.633 (D) 1.732

Q.5 A property that CANNOT be obtained from a tensile test is

(A) Young's modulus (B) yield strength
(C) ultimate tensile strength (D) endurance limit

Q.6 Intensive thermodynamic variables are

(A) independent of the number of moles in the system
(B) dependent on the volume of the system
(C) dependent on the mass of the system
(D) independent of the temperature of the system

Q.7 In a sound casting, the last liquid to solidify is in the

(A) runner (B) riser (C) gate (D) vent

Q.8 An annealed plain carbon steel, showing fully pearlitic microstructure, has a carbon content of

(A) 0.01 wt % (B) 0.20 wt % (C) 0.77 wt % (D) 1.20 wt %

Q.9 Superalloys are

(A) Al-based alloys (B) Cu-based alloys
(C) Ni-based alloys (D) Mg-based alloys

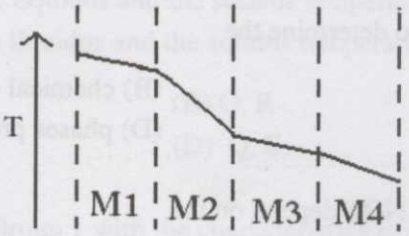
Q.10 Wood is a naturally occurring

(A) malleable material (B) composite material
(C) ceramic material (D) isotropic material

Q.11 The function, $f(x) = ax^2 + bx + c$ has a maxima only if

(A) $a < 0$ (B) $a > 0$ (C) $a = 0$ (D) $a > 0$ and $b < 0$

Q.12 A furnace wall consists of four layers of different materials, M1, M2, M3 and M4. If the layers are of equal thickness and the steady state temperature profile is, as shown below, then the material with the lowest thermal conductivity is



(A) M1 (B) M2 (C) M3 (D) M4

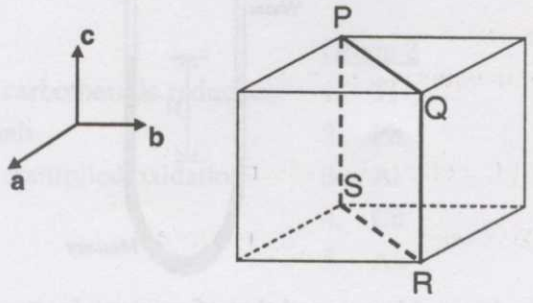
Q.13 From the list given below :

P. Cu
Q. Mg
R. Ni
S. Zn

Two metals which provide cathodic protection to steel are

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

Q.14 The Miller indices of the plane PQRS, shown in the unit cell, are



(A) (111) (B) $(1\bar{2}1)$ (C) $(\bar{1}10)$ (D) (100)

Q.15 A defect that is bounded by two mirror planes is

(A) twin
(B) stacking fault
(C) grain boundary
(D) edge dislocation

Q.16 $\lim_{x \to 0} \frac{\sin x}{x}$ is equal to

(A) 0 (B) 1 (C) ∞ (D) undefined

Q.17 Fick's first law relates

(A) flux of atoms and the concentration gradient
(B) amount of gas dissolved in the molten metal and the partial pressure
(C) applied normal stress and the orientation of slip system
(D) heat flux and the temperature gradient

Q.18 X-ray radiography is used to determine the

(A) soundness of casting
(B) chemical composition
(C) crystal structure
(D) phases present

Q.19 Hardenability of steel does NOT depend on the

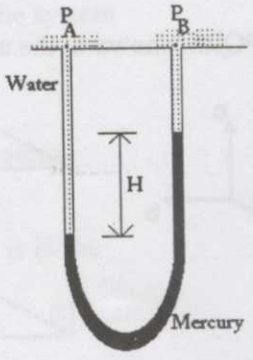
(A) alloy content
(B) grain size
(C) amount of carbon present
(D) amount of cold work

Q.20 *p*-type semiconductor can be obtained by doping silicon with

(A) antimony
(B) phosphorous
(C) arsenic
(D) boron

Q. 21 to Q. 60 carry two marks each.

Q.21 The figure below shows water over mercury manometer.



If the density of water is denoted by ρ_W and that of mercury by ρ_M and 'g' denotes the acceleration due to gravity, the pressure difference $(P_A - P_B)$ will be equal to

(A) $-(\rho_M\ g\ H)$ (B) $(\rho_W - \rho_M)\ g\ H$ (C) $\rho_M\ g\ H$ (D) $(\rho_M - \rho_W)\ g\ H$

Q.22 Match the processes given in Group 1 with the corresponding typical defects given in Group 2.

Group 1		Group 2	
P.	Forging	1.	Alligatoring
Q.	Rolling	2.	Cold shut
R.	Deep drawing	3.	Chevron cracks
S.	Extrusion	4.	Wrinkles

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

Q.23 From the list given below, two factors that promote coring in cast alloys are

P. slow cooling during solidification
Q. rapid cooling during solidification
R. small difference between the liquidus and the solidus temperatures
S. large difference between the liquidus and the solidus temperatures

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

Q.24 Match the loading conditions in Group 1 with the characteristics in Group 2.

Group 1		Group 2	
P.	Tensile	1.	Barreling
Q.	Compressive	2.	Intergranular cracking
R.	Fatigue	3.	Striations
S.	Creep	4.	Cup and cone
		5.	Earing

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

Q.25 Match the extraction methods in Group 1 with the metals in Group 2.

Group 1		Group 2	
P.	Roasting followed by carbothermic reduction	1.	Ti
Q.	Electrolysis of fused salt	2.	Pb
R.	Roasting followed by controlled oxidation	3.	Al
S.	Halide process	4.	Cu
		5.	Au

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

Q.26 The average molecular weight of high density polyethylene is found to b e degree of polymerization is

(A) 200 (B) 1000 (C) 2000 (D) 4000

Q.27 A 0.2 wt % C steel is carburized at 1200 K for 4 hours to obtain 0.8 wt % C at a depth of 0.2 Instead, if the carburizing is performed for 8 hours at the same temperature, then 0.8 wt % C wi achieved at a depth of

(A) 0.23 mm (B) 0.55 mm (C) 0.28 mm (D) 0.40 mm

Q.28 A unit dislocation with a Burgers vector $\vec{b}_1$ will dissociate into two partial dislocations with Burgers vectors $\vec{b}_2$ and $\vec{b}_3$, if and only if

P. $b_1^2 > b_2^2 + b_3^2$

Q. $b_1^2 < b_2^2 + b_3^2$

R. $\vec{b}_1 = \vec{b}_2 + \vec{b}_3$

S. $\vec{b}_1 \neq \vec{b}_2 + \vec{b}_3$

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

Q.29 The solution function $y = f(x)$ for the ordinary differential equation, $dy/dx = 3x^2 - 2x$, passes through (1,1). The magnitude of y at $x = 3$ is

(A) 0 (B) 18 (C) 19 (D) 21

Q.30 What is the magnitude of the following integral using single step application of trapezoidal rule ?

$$\int_0^2 (3x^2 + 4x - 2)dx$$

(A) 9 (B) 16 (C) 18 (D) 36

Q.31 During a sheet stamping operation, it is observed that sheet surface area triples. The true thickness strain is

(A) –1.1 (B) –0.333 (C) +0.333 (D) +1.1

Q.32 Match the practices in Group 1 with reactors in Group 2.

Group 1		Group 2	
P.	Layered charging of coke and ore	1.	Ladle furnace
Q.	Oxygen injection through supersonic nozzle	2.	Electric arc furnace
R.	Aluminium wire feeding	3.	Blast furnace
S.	Foamy slag practice	4.	LD converter

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

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

Q.33 For the reaction,

$$MO(Pure, Solid) + CO(gas) \rightarrow M(Pure, Solid) + CO_2\,(gas)$$

the equilibrium constant at 1000 K is 2.0. The oxide, MO, can be reduced to M at 1000 K, using a gas mixture containing

(A) 20% CO, 45% CO_2, 35% N_2 (B) 20% CO, 10% CO_2, 70% N_2

(C) 20% O_2, 80% N_2 (D) 50% N_2, 50% Ar

Q.34 Stacking fault energy (SFE) plays an important role in determining the work hardening ability of a metal. In this context, the correct logical sequence is

(A) High SFE → easy cross-slip → low work hardening

(B) High SFE → difficult cross-slip → high work hardening

(C) Low SFE → easy cross-slip → low work hardening

(D) Low SFE → difficult cross-slip → low work hardening

Q.35 Match the joining processes in Group 1 with the filler materials in Group 2.

Group 1		Group 2	
P.	Soldering	1.	Silver – Titanium alloy
Q.	Welding	2.	Silver – Tin alloy
R.	Brazing	3.	Mild steel
		4.	Lead flouride

(A) P-2, Q-3, R-1 (B) P-1, Q-2, R-3

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

Q.36 Match the properties in Group 1 with the metals in Group 2.

Group 1		Group 2	
P.	Ferromagnetism	1.	Nb
Q.	Superconductivity	2.	Fe
R.	Diamagnetism	3.	Cu
S.	Antiferromagnetism	4.	Cr

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

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

Q.37 Assertion **a** : During hardening of steel, the component to be heat treated is strongly agitated in the quenching medium.

Reason **r** : The agitation breaks down the vapour barrier allowing the quench to proceed at a more rapid rate.

(A) Both **a** and **r** are correct, but **r** is not the 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 correct and **r** is the correct reason for **a**.

Q.38 The activity of copper in the 'impure copper' is 0.5 at 298 K. The minimum voltage required to refine 'impure copper' to pure copper using an electrolyte having Cu^{2+} ions at 298 K is

(A) 0.9 mV (B) 9 mV (C) 90 mV (D) 900 mV

Q.39 A 3.0 mm diameter single crystal is loaded to 400 N along $[001]$ direction. The resolved shear stress on $(111)[\bar{1}01]$ slip system is

(A) 5.8 MPa (B) 11.5 MPa (C) 23.1 MPa (D) 46.2 MPa

Q.40 As per the TTT diagram, bainite will form in eutectoid plain carbon steel when heated to 850 °C followed by

(A) air-cooling to room temperature

(B) isothermal holding between eutectoid temperature and the nose

(C) quenching to room temperature

(D) isothermal holding between the nose and the M_s temperature

Q.41 The vapour pressure of pure liquid B at temperature T_0 is 0.5 atm. The partial pressure of B in the vapour phase that is in equilibrium with the liquid solution consisting of 30 mol% A and 70 mol% B at temperature T_0 is (assume both liquid and vapour phases behave ideally)

(A) 0.35 atm (B) 0.50 atm (C) 0.70 atm (D) 1.00 atm

Q.42 During low temperature plastic deformation of an under-aged precipitation hardened alloy, dislocations

(A) climb to completely avoid the precipitate

(B) loop around the precipitate

(C) cross-slip to completely avoid the precipitate

(D) cut through the precipitate

Q.43 According to Hume-Rothery rules, extensive solid solubility between elements X and Y is promoted by the two factors in the following list :

P. Same crystal structure of X and Y

Q. Large atomic size difference (> 20 %) between X and Y

R. Same valence of X and Y

S. Large difference in melting points of X and Y

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

Q.44 At constant temperature and pressure, two phases α and β will be in equilibrium when

(A) chemical potential of each component is the same in α and β

(B) partial molar free energy of each component is NOT the same in α and β

(C) Gibbs free energy of mixing is minimum

(D) enthalpy of mixing is zero

Q.45 The stress applied on a material is

$$\sigma_{ij} = \begin{bmatrix} 21 & 0 & 0 \\ 0 & 21 & 0 \\ 0 & 0 & 21 \end{bmatrix} \text{ MPa.}$$

The maximum shear stress experienced by it is

(A) 0 MPa (B) 10.5 MPa (C) 21 MPa (D) 63 MPa

Q.46 For the following reaction at 300 K,

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

the heat of reaction is 803 kJ/mol of CH_4. At 300 K, CH_4 – air gas mixture containing stoichiometric amount of oxygen is burnt to completion. Assuming, air contains 20 vol% O_2, 80 vol% N_2 and the specific heats for CO_2, H_2O (g) and N_2 are 50, 40 and 40 J mol^{-1} K^{-1} respectively, the adiabatic flame temperature will be

(A) 1684 K (B) 1784 K (C) 2084 K (D) 2384 K

Q.47 Match the properties in Group 1 with the testing techniques in Group 2.

Group 1		Group 2	
P.	Electrical conductivity	1.	Jominy test
Q.	Impact energy	2.	Izod test
R.	Thermal expansion	3.	Dilatometry
S.	Specific heat	4.	Four probe technique
		5.	Differential scanning calorimetry

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

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

Q.48 A blast furnace is charged with pure Fe_2O_3. For each ton of Fe produced, it discharges 700 kg of CO_2 and 450 kg of CO as top gas. The O_2 consumed, per ton of Fe produced, is

(A) 138 kg (B) 238 kg (C) 338 kg (D) 438 kg

Q.49 Taylor series can be used to approximate the value of $f(x) = \cos x$ by expanding around $x = 0$. If only the first three terms of the series are considered, the magnitude of deviation from the actual value of $\cos(\pi/3)$ will be

(A) 0.01 (B) 0.03 (C) 0.05 (D) 0.07

Q.50 A 200 mm × 200 mm cross-section bloom is continuously cast at a casting speed of 0.05 m/s. The amount of heat extracted from the 0.7 m long mould is 1.28 MW. Assume that the temperature of the steel is at its melting point while entering and leaving the mould. Latent heat of fusion for the steel is 278 kJ/kg and density of steel is 7800 kg/m^3. The thickness of the solidified shell emerging from the mould will be

(A) 0.147 mm (B) 1.47 mm (C) 14.7 mm (D) 147 mm

Common Data Questions

Common data for Questions 51 and 52:

A metallic rod with 2 mm × 2 mm square cross-section is being tested in tension and has the following mechanical properties:

Young's modulus = 100 GPa Poisson's ratio = 0.30

Yield stress = 500 MPa Work hardening exponent = 0.25

Ultimate tensile strength = 1000 MPa

Q.51 The rod is loaded to 1000 N, the magnitude of transverse strain is

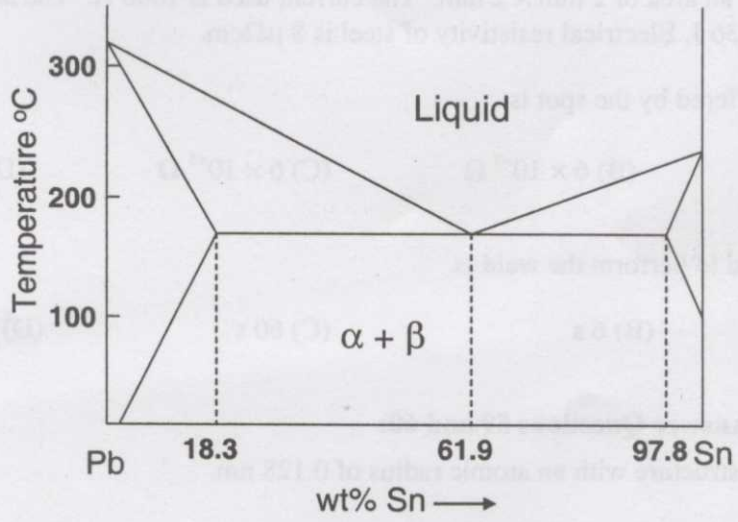
(A) 0.025% (B) 0.075% (C) 0.15% (D) 0.25%

Q.52 The modulus of resilience of the material is

(A) 0.25 MJ/m^3 (B) 0.50 MJ/m^3 (C) 0.75 MJ/m^3 (D) 1.25 MJ/m^3

Common data for Questions 53 and 54:

Schematic of the Pb-Sn phase diagram at atmospheric pressure is shown below.



Q.53 A Pb-Sn hypo-eutectic alloy is slowly cooled from the liquid state to room temperature. The composition of the alloy whose microstructure consists of 25 wt% lamellar constituent is

(A) Pb - 29.2 wt % Sn (B) Pb - 35.5 wt % Sn

(C) Pb - 40.8 wt % Sn (D) Pb - 61.9 wt % Sn

Q.54 The minimum and maximum degrees of freedom in the above binary system are

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

Common Data for Questions 55 and 56:

An operator in a steel plant wants to reduce the phosphorous level in steel by treating it with a slag. The equilibrium phosphorous distribution ratio between slag and liquid steel, i.e. (wt% of P in slag)/(wt% of P in steel) is 100 for the chosen slag composition. Assume before the treatment, the steel contains 0.2 wt% P.

Q.55 If the operator treats 1000 kg of liquid steel with 100 kg of slag, the resulting phosphorous content in liquid steel will be

(A) 0.001 % (B) 0.002 % (C) 0.010 % (D) 0.018 %

Q.56 Instead, the operator treats the 1000 kg of liquid steel with 50 kg of slag. Then, the processed slag is removed and another 50 kg of fresh slag is added. The resulting phosphorous content in steel will be

(A) 0.0015 % (B) 0.0030 % (C) 0.0055 % (D) 0.0090 %

Linked Answer Questions

Statement for Linked Answer Questions 57 and 58:

In automobile industry, electrical resistance welding is used for spot welding steel panels, each of 1.5 mm thickness. The weld has an area of 2 mm × 2 mm. The current used is 1000 A. The amount of heat required to melt this spot volume is 36 J. Electrical resistivity of steel is 8 μΩcm.

Q.57 The resistance offered by the spot is

(A) $6 \times 10^{-8}\ \Omega$ (B) $6 \times 10^{-5}\ \Omega$ (C) $6 \times 10^{+5}\ \Omega$ (D) $6 \times 10^{+8}\ \Omega$

Q.58 The time required to perform the weld is

(A) 0.6 s (B) 6 s (C) 60 s (D) 600 s

Statement for Linked Answer Questions 59 and 60:

Copper has FCC crystal structure with an atomic radius of 0.128 nm.

Q.59 The interplanar spacing for (220) planes in copper is

(A) 0.064 nm (B) 0.128 nm (C) 0.181 nm (D) 0.256 nm

Q.60 In an X-ray diffraction experiment, radiation of wavelength 0.154 nm is used. Assuming the order of reflection to be 1, the Bragg angle for the (220) set of planes in copper will be

(A) 12.56° (B) 36.98° (C) 48.98° (D) 74.21°

END OF THE QUESTION PAPER