OJEE MTech Mettalurgical Sample Paper 02

A) Mode and Time: The exam is a Computer Based Test (CBT) lasting 120 minutes.
B) Total Questions: The exam contains 90 questions.
C) Marking Scheme & Rules:

- +4 marks for each correct answer; -1 mark for each incorrect answer.

Q1. In the context of nucleation during phase transformations, the 'Zeldovich factor' accounts for:

A. The reduction in nucleation rate due to the dissolution of sub-critical clusters

B. The strain energy associated with a coherent nucleus

C. The specific volume difference between liquid and solid phases

D. The change in chemical potential at the interface

Q2. During the reduction of iron ore in a blast furnace, which of the following iron oxides has the highest equilibrium CO/CO2 ratio for its reduction to metallic iron at 1000°C?

A. Hematite (Fe2O3)

B. Magnetite (Fe3O4)

C. Wustite (FeO)

D. They all require the same ratio

Q3. In a tensile test of a polymeric material, 'crazing' is typically a precursor to:

A. Ductile yielding

B. Brittle fracture

C. Strain hardening

D. Superplastic flow

Q4. Which parameter is mathematically maximized at the exact composition of a congruent melting point in a binary phase diagram?

A. Enthalpy of mixing

B. Entropy of fusion

C. Gibbs free energy of the liquid phase

D. Melting temperature relative to surrounding compositions

Q5. The 'Ternary Gibbs Phase Rule' for a system at constant pressure is given by:

A. F = 3 - P + 1

B. F = 3 - P + 2

C. F = C - P + 1

D. F = C - P + 2

Q6. In classical dislocation theory, the force per unit length (F/L) acting on a dislocation line due to an applied shear stress (tau) is given by the Peach-Koehler equation as:

A. F/L = tau / b

B. F/L = tau * b

C. F/L = tau * b^2

D. F/L = mu * b / tau

Q7. Which advanced surface characterization technique utilizes the ejection of core-level electrons by X-ray photons to determine the chemical states of surface elements?

A. Scanning Electron Microscopy (SEM)

B. X-ray Diffraction (XRD)

C. X-ray Photoelectron Spectroscopy (XPS)

D. Transmission Electron Microscopy (TEM)

Q8. The presence of retained austenite in quenched high-carbon steel is generally undesirable for dimensional stability because it can slowly transform into:

A. Pearlite at room temperature

B. Untempered martensite, accompanied by a volume expansion

C. Cementite, causing severe embrittlement

D. Ferrite, reducing the overall hardness

Q9. In the context of quantitative metallography, ASTM grain size number (n) is defined by the equation $N = 2^(n-1), where N represents$:

A. The number of grains per square inch at 100x magnification

B. The number of grains per square millimeter at 1x magnification

C. The average grain diameter in micrometers

D. The number of grain boundary intersections per unit length

Q10. The principal ore of Lead, Galena, is typically concentrated by which of the following mineral processing techniques prior to smelting?

A. Magnetic separation

B. Gravity concentration

C. Froth flotation

D. Leaching

Q11. A steel component fails due to high-cycle fatigue. Examination of the fracture surface via SEM is most likely to reveal:

A. Extensive microvoid coalescence

B. Intergranular cleavage facets

C. Fatigue striations

D. A purely fibrous morphology

Q12. According to the classic Wagner theory of internal oxidation, the transition from internal oxidation to the formation of an external protective scale is promoted by:

A. High oxygen partial pressure in the atmosphere

B. High concentration of the reactive solute in the alloy

C. High diffusion rate of oxygen in the metal matrix

D. Low temperature

Q13. In arc welding, the phenomenon of 'Arc Blow' is most commonly encountered when welding with:

A. AC current on non-magnetic materials

B. DC current on magnetic materials

C. AC current on magnetic materials

D. DC current on non-magnetic materials

Q14. The thermodynamic 'activity coefficient' approaches unity as the mole fraction of the component approaches unity. This describes the limiting behavior known as:

A. Henry's Law

B. Sieverts' Law

C. Raoult's Law

D. Fick's Law

Q15. Which of the following processes is NOT a solid-state severe plastic deformation (SPD) technique used to produce ultrafine-grained materials?

A. Equal Channel Angular Pressing (ECAP)

B. High-Pressure Torsion (HPT)

C. Accumulative Roll Bonding (ARB)

D. Splat Quenching

Q16. In the iron-carbon phase diagram, the Acm line represents the boundary where:

A. Austenite begins to transform into ferrite upon cooling

B. Austenite begins to transform into pearlite upon cooling

C. Proeutectoid cementite begins to precipitate from austenite upon cooling

D. Delta ferrite transforms into austenite

Q17. The process of 'Cupola' melting is predominantly used in foundries for the production of:

A. Aluminum alloys

B. Cast irons

C. Titanium alloys

D. Stainless steels

Q18. The 'Peltier effect' in thermoelectric materials refers to:

A. The generation of a voltage due to a temperature gradient

B. The emission of electrons from a heated surface

C. The absorption or emission of heat at a junction of two different conductors when a current passes through

D. The change in electrical resistance due to an applied magnetic field

Q19. Which equation is used to predict the critical resolved shear stress required for a dislocation to bypass a closely spaced array of impenetrable precipitates?

A. Hall-Petch equation

B. Orowan equation

C. Cottrell-Stokes law

D. Nabarro-Herring equation

Q20. In physical metallurgy, a 'spinodal decomposition' is a phase transformation mechanism characterized by:

A. Nucleation and growth of a new phase at grain boundaries

B. A diffusionless, military shear transformation

C. Uphill diffusion causing spontaneous phase separation without a nucleation barrier

D. The formation of a Widmanstatten microstructure

Q21. During the deep drawing of a sheet metal blank, the ideal material properties to prevent failure (tearing) include:

A. High yield strength and low ductility

B. Low normal anisotropy (r-value) and high planar anisotropy

C. High normal anisotropy (r-value) and a high strain hardening exponent (n-value)

D. Low strain hardening exponent and high ultimate tensile strength

Q22. In continuous casting of steel, 'oscillation marks' on the surface of the cast strand are primarily caused by:

A. Variations in the cooling water temperature

B. The cyclic up-and-down movement of the water-cooled copper mold

C. Electromagnetic stirring of the liquid core

D. Segregation of carbon and sulfur at the meniscus

Q23. The susceptibility of a material to 'Hydrogen Embrittlement' generally increases with:

A. Decreasing yield strength

B. Increasing yield strength and hardness

C. Increasing temperature above 200°C

D. Increasing grain size

Q24. According to Fick's Second Law, the concentration profile for non-steady state diffusion into a semi-infinite solid from a constant surface concentration follows an analytical solution involving the:

A. Error function (erf)

B. Bessel function

C. Exponential decay function

D. Logarithmic function

Q25. Which of the following elements is a strong 'austenite former' and is added to stainless steels to make them austenitic at room temperature?

A. Chromium

B. Molybdenum

C. Nickel

D. Titanium

Q26. The minimum energy required to create a new surface during brittle fracture is analytically defined by the:

A. Young's modulus

B. Poisson's ratio

C. Specific surface energy

D. Strain energy density

Q27. In the Bayer process for refining bauxite, the 'red mud' waste product is primarily composed of:

A. Aluminum hydroxide

B. Sodium aluminate

C. Iron oxides, titanium dioxide, and silica

D. Cryolite

Q28. The 'Jominy end-quench test' is standardized to measure which specific property of a steel?

A. Fracture toughness

B. Hardenability

C. Creep resistance

D. Fatigue strength

Q29. Which non-destructive testing (NDT) technique relies on the capillary action of a fluid to detect surface-breaking defects?

A. Magnetic Particle Inspection (MPI)

B. Dye Penetrant Testing (DPT)

C. Radiographic Testing (RT)

D. Eddy Current Testing (ECT)

Q30. In classical thermodynamics, at a constant temperature and pressure, a closed system will spontaneously change to minimize its:

A. Enthalpy

B. Entropy

C. Gibbs free energy

D. Helmholtz free energy

Q31. During the extraction of titanium via the Kroll process, the reduction of Titanium Tetrachloride (TiCl4) to titanium sponge is typically achieved using molten:

A. Sodium

B. Calcium

C. Magnesium

D. Aluminum

Q32. Which strengthening mechanism relies on the distortion of the crystal lattice caused by interstitial or substitutional solute atoms of different sizes?

A. Work hardening

B. Precipitation hardening

C. Solid solution strengthening

D. Grain boundary strengthening

Q33. In the context of solidification, 'Chvorinov's Rule' states that the solidification time of a casting is proportional to:

A. (Volume / Surface Area)

B. $(\text{Volume} / \text{Surface Area})^2$

C. $(\text{Surface Area} / \text{Volume})^2$

D. Volume * Surface Area

Q34. The microstructural constituent 'Spheroidite' in steels is formed by:

A. Rapid quenching of austenite to martensite

B. Isothermal transformation of austenite at 400°C

C. Prolonged heating of pearlite or bainite just below the eutectoid temperature

D. Severe cold working of ferrite

Q35. Which of the following welding processes uses a non-consumable tungsten electrode and an inert shielding gas?

A. GMAW (MIG)

B. SMAW (Stick)

C. FCAW

D. GTAW (TIG)

Q36. In the stress-strain curve of a mild steel, the 'lower yield point' represents the stress at which:

A. The specimen fractures

B. Macroscopic plastic deformation becomes heterogeneous and localized (Lüders bands)

C. Dislocations break free from Cottrell atmospheres and multiply rapidly

D. The maximum load-bearing capacity is reached

Q37. Which mechanism dominates the high-temperature, low-stress creep of coarse-grained materials by mass transport through the crystal lattice?

A. Nabarro-Herring creep

B. Coble creep

C. Dislocation glide

D. Grain boundary sliding

Q38. In an E-pH (Pourbaix) diagram, a vertical line separating two chemical species indicates an equilibrium reaction that is:

A. Dependent purely on potential (electron transfer)

B. Dependent purely on pH (proton transfer)

C. Dependent on both potential and pH

D. Independent of both potential and pH

Q39. The term 'Hardenability' in steel heat treatment specifically refers to:

A. The maximum hardness achievable, which depends only on carbon content

B. The depth to which a steel can be hardened by transforming to martensite

C. The resistance of the steel to tempering

D. The amount of energy the steel can absorb before fracture

Q40. During the conversion of copper matte in a Pierce-Smith converter, the 'slag-making stage' primarily removes:

A. Sulfur as SO2 gas

B. Copper as Cu2O

C. Iron as FeO, which fluxes with silica to form fayalite slag

D. Precious metals into the slag

Q41. The 'Hall-Petch relationship' mathematically links the yield strength of a poly-crystalline metal to its:

A. Dislocation density

B. Grain size

C. Strain rate

D. Solute concentration

Q42. In X-ray diffraction, if the lattice parameter of a cubic crystal decreases, the Bragg diffraction peaks will:

A. Shift to higher $2heta$ angles

B. Shift to lower $2heta$ angles

C. Remain at the same angle but broaden

D. Decrease in intensity without shifting

Q43. Which parameter defines the ratio of the lateral strain to the axial strain in a material subjected to uniaxial tension?

A. Young's modulus

B. Shear modulus

C. Poisson's ratio

D. Bulk modulus

Q44. The 'Boudouard reaction' in the blast furnace is represented by:

A. $C + O_2 = CO_2$

B. $C + H_2O = CO + H_2$

C. $C + CO_2 = 2CO$

D. $FeO + CO = Fe + CO_2$

Q45. Superplastic deformation is typically characterized by a strain rate sensitivity index (m) that is:

A. Close to 0

B. Between 0.1 and 0.2

C. Between 0.4 and 0.8

D. Exactly 1.0 (Newtonian fluid)

Q46. The driving force for steady-state grain growth following primary recrystallization is the:

A. Release of stored strain energy

B. Minimization of total grain boundary interfacial energy

C. Chemical concentration gradients

D. Thermal stresses from cooling

Q47. In linear elastic fracture mechanics, the stress intensity factor (K) ahead of a sharp crack of length 'a' subjected to a nominal tensile stress 'σ' is proportional to:

A. $\sigma \cdot a$

B. $\sigma^2 \cdot a$

C. $\sigma \cdot \sqrt{a}$

D. $\sigma / \sqrt{a}$

Q48. Which electrochemical technique applies a varying potential to an electrode and records the resulting current to study oxidation-reduction reactions?

A. Electrochemical Impedance Spectroscopy (EIS)

B. Cyclic Voltammetry (CV)

C. Potentiometric titration

D. Galvanostatic polarization

Q49. The primary purpose of adding limestone ($CaCO_3$) to the ironmaking blast furnace is to:

A. Reduce the iron oxide to metallic iron

B. Provide carbon for the Boudouard reaction

C. Decompose into CaO to flux the acidic gangue impurities into a fluid slag

D. Lower the overall temperature of the furnace

Q50. Which defect is specific to deep drawing operations and manifests as a series of ridges or folds around the flange of the drawn cup?

A. Earing

B. Wrinkling

C. Orange peel

D. Necking

Q51. In an isomorphous binary phase diagram, the 'liquidus' line represents the locus of points where:

A. The liquid phase completely solidifies

B. Solidification begins upon cooling from the liquid state

C. Two solid phases are in equilibrium

D. A peritectic reaction occurs

Q52. Sensitization of austenitic stainless steels makes them susceptible to intergranular corrosion. This can be mitigated by:

A. Heating to 600°C and holding for 2 hours

B. Adding strong carbide formers like Titanium or Niobium

C. Increasing the carbon content of the steel

D. Quenching rapidly from 500°C

Q53. In powder metallurgy, the process of 'liquid phase sintering' is heavily reliant on:

A. Vapor phase transport between particles

B. High capillary forces generated by a wetting liquid phase

C. Cold welding during initial compaction

D. Solid-state volume diffusion exclusively

Q54. The 'Portevin-Le Chatelier' (PLC) effect, observed as serrations on a stress-strain curve, is a macroscopic manifestation of:

A. Dynamic recovery

B. Dynamic recrystallization

C. Dynamic strain aging

D. Deformation twinning

Q55. Which parameter is defined as the total area under the engineering stress-strain curve up to the point of fracture?

A. Resilience

B. Toughness

C. Yield strength

D. Ultimate Tensile Strength

Q56. According to Sieverts' Law, the solubility of a diatomic gas (like Hydrogen or Nitrogen) in a liquid metal is proportional to the:

A. Partial pressure of the gas

B. Square root of the partial pressure of the gas

C. Square of the partial pressure of the gas

D. Inverse of the partial pressure of the gas

Q57. In a galvanic corrosion cell involving Iron and Zinc immersed in seawater, Zinc acts as the:

A. Cathode and is protected from corrosion

B. Anode and is protected from corrosion

C. Anode and corrodes to protect the Iron

D. Cathode and corrodes

Q58. The 'Austempering' heat treatment of steel is designed to produce a microstructure consisting entirely of:

A. Martensite

B. Pearlite

C. Bainite

D. Spheroidite

Q59. Which of the following is an example of an invariant reaction where a single solid phase transforms into two distinct solid phases upon cooling?

A. Eutectic

B. Eutectoid

C. Peritectic

D. Monotectic

Q60. In the context of extractive metallurgy, 'Electrowinning' is a process used to:

A. Purify an already cast metal anode

B. Deposit metal onto a cathode from an aqueous or fused salt electrolyte

C. Remove impurities from a slag

D. Reduce iron ore using hydrogen gas

Q61. The determinant of an orthogonal matrix is always:

A. 0

B. 1 or -1

C. Equal to its trace

D. Infinity

Q62. If A and B are independent events with $P(A) = 0.6$ and $P(B) = 0.5$, what is the probability of $P(A \cup B)$?

A. 0.3

B. 0.8

C. 1.1

D. 0.9

Q63. Evaluate the limit: $\lim_{xo0}$
rac1 - $\cos xx^2$

A. 0

B. 1

C. 1/2

D. Infinity

Q64. The divergence of the curl of any continuous, twice-differentiable vector field **F** is always:

A. The gradient of **F**

B. The Laplacian of **F**

C. Zero

D. A non-zero constant

Q65. Which of the following is the Laplace transform of t^n (where n is a positive integer)?

A. $n!/s^{n+1}$

B. n/s^n

C. $1/s^{n+1}$

D. $n!/s^n$

Q66. A matrix A has eigenvalues $\lambda_1 = 2$ and $\lambda_2 = 3$. What are the eigenvalues of the matrix A^2?

A. 2, 3

B. 4, 9

C. 5, 6

D. 1/2, 1/3

Q67. The differential equation
racdydx + P(x)y = Q(x)y^n is known as:

A. Euler-Cauchy equation

B. Bernoulli equation

C. Riccati equation

D. Clairaut's equation

Q68. The area enclosed by the curve $y = \sin x$ and the x-axis from $x = 0$ to $x = \pi$ is:

A. 0

B. 1

C. 2

D. π

Q69. Which numerical method uses the slope at the beginning of the interval to predict the function value at the end of the interval?

A. Simpson's rule

B. Runge-Kutta 4th order

C. Euler's method

D. Newton-Raphson method

Q70. If $z = x + iy$, the complex function $f(z) = |z|^2$ is differentiable:

A. Everywhere in the complex plane

B. Nowhere

C. Only at the origin $z = 0$

D. Along the real axis only

Q71. What is the rank of the matrix $A = \begin{pmatrix} 1 & 2 \\ 3 & 6 \end{pmatrix}$?

A. 0

B. 1

C. 2

D. 3

Q72. The probability of drawing a 'Spade' or a 'King' from a standard 52-card deck is:

A. 16/52

B. 17/52

C. 4/13

D. 1/13

Q73. The directional derivative of a scalar function $f(x, y, z)$ is maximum in the direction of:

A. The x-axis

B. The curl of the field

C. The gradient vector $ablaf$

D. A unit vector orthogonal to the gradient

Q74. The Newton-Raphson iterative formula for finding the root of $f(x) = 0$ is:

A. $x_{n+1} = x_n + f(x_n)/f'(x_n)$

B. $x_{n+1} = x_n - f(x_n)/f'(x_n)$

C. $x_{n+1} = x_n - f'(x_n)/f(x_n)$

D. $x_{n+1} = f(x_n) - x_n f'(x_n)$

Q75. Evaluate the cross product $\mathbf{i}times(\mathbf{j}times\mathbf{k})$.

A. $\mathbf{0}$ (Zero vector)

B. $\mathbf{i}$

C. $\mathbf{j}$

D. $\mathbf{k}$

Q76. A bag contains 5 red balls and 3 blue balls. If two balls are drawn without replacement, what is the probability they are both red?

A. 25/64

B. 5/14

C. 10/28

D. 20/56

Q77. The general solution to the differential equation $y'' + 9y = 0$ is:

A. $y = C_1 e^{3x} + C_2 e^{-3x}$

B. $y = (C_1 + C_2 x)e^{3x}$

C. $y = C_1 \sin(3x) + C_2 \cos(3x)$

D. $y = C_1 \sinh(3x) + C_2 \cosh(3x)$

Q78. In complex analysis, if a function has a pole of order m at $z = a$, then the residue of the function at $z = a$ is given by a formula involving the:

A. $(m-1)$-th derivative

B. m-th derivative

C. $(m+1)$-th derivative

D. Integral of the function

Q79. Which of the following functions is an 'even' function?

A. $f(x) = \sin(x)$

B. $f(x) = x^3$

C. $f(x) = \cos(x)$

D. $f(x) = e^x$

Q80. Applying the trapezoidal rule to integrate $f(x) = x$ from $x = 0$ to $x = 2$ with 1 interval gives:

A. 1

B. 2

C. 3

D. 4

Q81. If 'R' means 'divided by', 'T' means 'added to', 'M' means 'subtracted from' and 'K' means 'multiplied by', then: 15 K 4 R 2 T 6 M 3 = ?

A. 27

B. 33

C. 36

D. 42

Q82. A is the brother of B. C is the father of A. D is the brother of E. E is the daughter of B. How is D related to A?

A. Uncle

B. Nephew

C. Cousin

D. Brother

Q83. Complete the series: 1, 4, 9, 16, 25, 36, ?

A. 47

B. 49

C. 52

D. 64

Q84. A girl walks 10 km towards the North. From there, she walks 6 km towards the South. Then, she walks 3 km towards the East. How far and in which direction is she with reference to her starting point?

A. 5 km North-East

B. 5 km South-East

C. 7 km East

D. 4 km North

Q85. Statement 1: All engineers are logical. Statement 2: Some logical people are scientists. Conclusion: Some engineers are scientists.

A. True

B. False

C. Cannot be determined

D. Logically inconsistent

Q86. If 'MERCURY' is written as 'FGIECGI' in a certain code, how would 'CURE' be written in that code?

A. ECGI

B. CEIG

C. ECIG

D. EICG

Q87. Data Sufficiency - Question: What is the exact temperature of the furnace? Statement 1: It is between 1000°C and 1100°C. Statement 2: It is a multiple of 50°C.

A. Statement 1 alone is sufficient

B. Statement 2 alone is sufficient

C. Both statements together are sufficient

D. Both statements together are NOT sufficient

Q88. Choose the odd word out:

A. Austenite

B. Cementite

C. Ferrite

D. Bauxite

Q89. A clock is set right at 5 AM. The clock loses 16 minutes in 24 hours. What will be the true time when the clock indicates 10 PM on the 4th day?

A. 11 PM

B. 10 PM

C. 9 PM

D. 8 PM

Q90. Which word cannot be formed using the letters of the word 'METALLURGICAL'?

A. METAL

B. ALLERGY

C. RURAL

D. GULL

Solutions

1. A
Explanation: The Zeldovich factor is a thermodynamic correction applied to the steady-state nucleation rate to account for the probability that some nuclei, even after reaching the critical size, may randomly dissolve back into the matrix due to thermal fluctuations.

2. C
Explanation: According to the Baur-Glaessner diagram, the reduction of Wustite (FeO) to metallic Fe requires a highly reducing atmosphere (high CO/CO2 ratio) compared to the reduction of higher oxides like Hematite and Magnetite.

3. B
Explanation: Crazing involves the localized yielding of polymers forming a network of microvoids bridged by highly oriented polymer fibrils. It absorbs energy but typically acts as a precursor to macroscopic brittle fracture under tensile stress.

4. D
Explanation: At a congruent melting point, the solid and liquid phases have identical compositions in equilibrium. It appears as a local maximum (or minimum) on the liquidus/solidus curves, indicating maximum thermal stability for that specific intermediate compound.

5. A
Explanation: The general Gibbs phase rule is F = C - P + 2. For a ternary system (C = 3) at constant pressure (using up one degree of freedom), the rule simplifies to F = 3 - P + 1, or F = 4 - P.

6. B
Explanation: The Peach-Koehler force describes the mechanical force acting on a dislocation due to an applied stress field. For a simple shear stress parallel to the Burgers vector, the magnitude of the force per unit length is F/L = tau * b.

7. C
Explanation: XPS, also known as ESCA (Electron Spectroscopy for Chemical Analysis), irradiates a surface with X-rays and measures the kinetic energy of the emitted core electrons to determine elemental composition and chemical bonding states.

8. B
Explanation: Retained austenite is metastable at room temperature. Over time, or during sub-zero service, it can spontaneously transform into brittle, untempered martensite. Because martensite has a lower density (higher volume) than austenite, this causes dimensional changes and internal stress.

9. A
Explanation: The standard ASTM grain size formula is $N = 2^{(n-1)}$.

10. C
Explanation: Galena (PbS) is a sulfide mineral.

11. C
Explanation: High-cycle fatigue failure is characterized by crack propagation oc-

curring over thousands of cycles. Each load cycle can leave a microscopic ridge on the fracture surface known as a fatigue striation, which is visible under a scanning electron microscope (SEM).

12. B

Explanation: To form a continuous external scale, the flux of the reactive solute metal to the surface must be sufficient to consume the incoming oxygen. Therefore, a higher bulk concentration of the reactive solute favors external scale formation over internal precipitation.

13. B

Explanation: Arc blow is the deflection of the electric arc from its intended path due to unbalanced magnetic fields surrounding the weld. It is most severe when using Direct Current (DC) on magnetic materials like steel, as the steady current sets up a strong, directional magnetic field.

14. C

Explanation: Raoult's Law describes the ideal behavior of a solvent in a solution. As the concentration of a component approaches purity (mole fraction approaches 1), its behavior approaches that of the pure substance, and its activity equals its mole fraction (activity coefficient = 1).

15. D

Explanation: ECAP, HPT, and ARB are all SPD techniques that introduce massive strains into a solid metal to refine its grain size without changing its macroscopic dimensions. Splat quenching is a rapid solidification technique from the liquid state.

16. C

Explanation: The Acm line defines the solid solubility limit of carbon in face-centered cubic austenite. For hypereutectoid steels, cooling below this line causes the excess carbon to precipitate out as a network of proeutectoid cementite at the austenite grain boundaries.

17. B

Explanation: A cupola furnace is a vertical, cylindrical shaft furnace historically and currently used extensively in foundries to melt pig iron, scrap steel, and ferroalloys with coke to produce large volumes of molten cast iron.

18. C

Explanation: The Peltier effect is the thermocooling or thermoheating phenomenon where passing an electrical current through a junction of two dissimilar thermoelectric materials causes heat to be absorbed or released, depending on the direction of the current.

19. B

Explanation: The Orowan equation models precipitation hardening via the bowing mechanism. It relates the increase in yield stress to the shear modulus, the Burgers vector, and inversely to the effective interparticle spacing of the precipitates.

20. C

Explanation: Spinodal decomposition occurs within a miscibility gap where the second derivative of the Gibbs free energy is negative. This renders the solid solution

absolutely unstable, leading to spontaneous phase separation via 'uphill' diffusion against the concentration gradient without any nucleation barrier.

21. C
Explanation: A high normal anisotropy (Lankford r-value) indicates resistance to thinning, preventing tearing. A high strain hardening exponent (n-value) ensures that the material distributes strain uniformly rather than necking prematurely.

22. B
Explanation: The mold in continuous casting is oscillated vertically to prevent the solidifying steel shell from sticking to the copper walls. This cyclical movement, combined with the infiltration of mold flux, creates distinct transverse ripples or oscillation marks on the strand surface.

23. B
Explanation: High-strength steels (with high yield strength and hardness) are particularly susceptible to hydrogen embrittlement. The trapped hydrogen reduces the cohesive strength of the lattice, leading to sudden, catastrophic brittle failure under tensile stress.

24. A
Explanation: Fick's Second Law for diffusion into a semi-infinite medium with a constant surface concentration (C_s) and initial bulk concentration (C_0) is solved using the Gaussian error function: $(C(x,t) - C_0)/(C_s - C_0) = 1 - erf(x/2\sqrt{Dt})$.

25. C
Explanation: Nickel is a Face-Centered Cubic (FCC) metal that strongly stabilizes the FCC austenite phase in iron. Adding sufficient nickel (e.g., 8 per cent in 304 stainless steel) suppresses the transformation to ferrite, keeping the steel austenitic at room temperature.

26. C
Explanation: In Griffith's theory of brittle fracture, the thermodynamic energy penalty for crack propagation is the creation of two new surfaces. This is governed by the specific surface energy (gamma), making the total energy requirement 2*gamma per unit area.

27. C
Explanation: During the Bayer process, bauxite is digested in NaOH. The alumina dissolves as sodium aluminate, while the insoluble impurities—predominantly iron oxides (which give it the red color), silica, and titania—are filtered out as 'red mud'.

28. B
Explanation: The Jominy test measures hardenability, which is the ability of a steel to form martensite at depth upon quenching. A standard bar is quenched from one end, and a hardness profile is measured along its length to see how deeply the hardening effect penetrates.

29. B
Explanation: Dye Penetrant Testing applies a low-surface-tension liquid dye to the material. Capillary action draws the dye into any surface-breaking cracks or pores. After cleaning, a developer draws the dye back out, creating a highly visible

indication.

30. C
Explanation: The fundamental criterion for spontaneity in a closed system held at constant temperature and pressure is a decrease in the Gibbs free energy ($dG < 0$). Equilibrium is reached when Gibbs free energy is minimized ($dG = 0$).

31. C
Explanation: In the Kroll process, purified liquid $TiCl_4$ is reacted with molten magnesium in a sealed stainless steel retort under an argon atmosphere. The exothermic reaction yields solid titanium 'sponge' and liquid magnesium chloride ($MgCl_2$).

32. C
Explanation: Solid solution strengthening occurs when solute atoms (either larger or smaller than the host atoms) create localized strain fields in the lattice. These strain fields interact with and impede the motion of dislocations, thereby increasing the yield strength.

33. B
Explanation: Chvorinov's rule ($t = B(V/A)^2$) empirically relates the total solidification time (t) of a casting to the square of its volume-to-surface-area ratio, indicating that larger, bulkier shapes take much longer to freeze than thin, extensive ones.

34. C
Explanation: Spheroidite is the most stable and ductile microstructure in steel. It forms when pearlite or bainite is heated to a temperature just below the eutectoid (e.g., 700°C) for many hours, causing the cementite to minimize its surface energy by agglomerating into distinct spherical particles.

35. D
Explanation: Gas Tungsten Arc Welding (GTAW), commonly known as TIG welding, establishes an arc between a non-consumable tungsten electrode and the workpiece, using an inert gas (like Argon or Helium) to shield the weld pool from atmospheric contamination.

36. C
Explanation: In metals with a distinct yield point, the upper yield point is required to unpin dislocations from interstitial solute clouds (Cottrell atmospheres). Once freed, they multiply rapidly, and deformation continues at a slightly lower, constant stress known as the lower yield point.

37. A
Explanation: Nabarro-Herring creep involves the diffusion of vacancies through the bulk crystal lattice (volume diffusion) driven by an applied stress. It dominates at very high temperatures where lattice mobility is high, especially in coarse-grained materials.

38. B
Explanation: In a Pourbaix diagram, the x-axis is pH and the y-axis is potential (E). A vertical line represents a chemical reaction that involves H^+ or OH^- ions but no electrons (no oxidation state change), making it purely dependent on pH.

39. B

Explanation: Hardenability is not maximum hardness; it is a measure of how easily a steel forms martensite upon quenching, dictating the depth of hardening. High hardenability allows thicker sections to harden completely to the core.

40. C

Explanation: The copper converting process has two stages. The first is the slag-making stage, where air is blown through the matte to selectively oxidize FeS to FeO. Silica is added, reacting with the FeO to form a fluid iron-silicate (fayalite) slag that is poured off.

41. B

Explanation: The Hall-Petch equation ($\sigma_y = \sigma_0 + kd^{-1/2}$) establishes that the yield strength of a metal is inversely proportional to the square root of its average grain diameter (d). Finer grains create more grain boundaries, which impede dislocation motion.

42. A

Explanation: According to Bragg's Law ($\lambda = 2d \sin heta$), the interplanar spacing (d) is directly proportional to the lattice parameter. If d decreases, $\sin heta$ (and thus the $2heta$ angle) must increase to satisfy the equation for a constant X-ray wavelength (λ).

43. C

Explanation: Poisson's ratio (u) is a fundamental mechanical property defined as the negative ratio of transverse (lateral) strain to axial (longitudinal) strain when a material is stretched or compressed in a single direction.

44. C

Explanation: The Boudouard reaction is the strongly endothermic reaction of solid carbon (from coke) with carbon dioxide gas to produce carbon monoxide ($C + CO_2 ightleftharpoons 2CO$). This is the primary source of the reducing gas (CO) in the blast furnace.

45. C

Explanation: Superplastic materials resist localized necking because their flow stress is highly sensitive to the strain rate. This corresponds to a high strain rate sensitivity index (m), typically in the range of 0.4 to 0.8.

46. B

Explanation: After primary recrystallization consumes the heavily deformed structure (driven by stored strain energy), the new grains will continue to grow to minimize the total area of the high-energy grain boundaries, driving normal grain growth.

47. C

Explanation: The stress intensity factor K defines the magnitude of the stress field near the crack tip. Its general form is $K = Y \cdot \sigma \cdot \sqrt{\pi a}$, showing that K is directly proportional to the applied stress and the square root of the crack length.

48. B

Explanation: Cyclic Voltammetry is a powerful electroanalytical method where the working electrode potential is swept linearly versus time back and forth be-

tween two limits, and the resulting current from redox reactions is plotted against the potential.

49. C

Explanation: Limestone is added as a basic flux. At high temperatures, it calcines into calcium oxide (CaO) and CO2. The basic CaO then reacts with acidic impurities in the ore (like silica, SiO_2, and alumina, Al_2O_3) to form a low-melting, highly fluid liquid slag.

50. B

Explanation: During deep drawing, the outer flange is drawn radially inward, causing its circumference to shrink. This induces severe compressive hoop stresses. If the blank holder force is insufficient to suppress buckling, the sheet will fold into wrinkles.

51. B

Explanation: The liquidus line is the upper phase boundary on a phase diagram. When cooling a completely liquid alloy, it represents the exact temperature at which the very first solid crystal thermodynamically nucleates.

52. B

Explanation: Sensitization is caused by chromium carbide precipitation at grain boundaries. Adding elements like Titanium or Niobium (which have a higher affinity for carbon than chromium does) 'stabilizes' the steel by forming inert carbides, keeping the chromium in solution for corrosion resistance.

53. B

Explanation: In liquid phase sintering, a minor component melts. If this liquid 'wets' the solid particles (low contact angle), the surface tension generates massive capillary pull, rapidly rearranging the solid particles and eliminating pores to achieve high density.

54. C

Explanation: The PLC effect is caused by dynamic strain aging, an ongoing race between mobile dislocations and diffusing solute atoms. Solutes repeatedly pin the moving dislocations (causing stress to rise) until the dislocations break free (causing a stress drop), creating serrations.

55. B

Explanation: Toughness is a measure of the total energy a material can absorb per unit volume before it ruptures. Mathematically, it is the integral of the stress-strain curve from zero strain to the fracture strain.

56. B

Explanation: Because a diatomic gas molecule (X_2) dissociates into two individual atoms ($2X$) upon dissolving into the liquid metal lattice, thermodynamic equilibrium dictates that its solubility is proportional to the square root of its partial pressure over the melt.

57. C

Explanation: Zinc is more electrochemically active (anodic) than iron. When electrically connected in an electrolyte, a galvanic cell forms where zinc acts as the sacrificial anode, corroding preferentially while supplying electrons to protect the

iron cathode.

58. C

Explanation: Austempering involves austenitizing the steel, then quenching it into a molten salt bath held precisely at a temperature within the bainite transformation range, and holding it there until it fully transforms into tough, ductile bainite.

59. B

Explanation: A eutectoid reaction is a solid-state invariant transformation where one solid phase (e.g., austenite) transforms simultaneously into two new, intimately mixed solid phases (e.g., ferrite and cementite) upon cooling past the eutectoid temperature.

60. B

Explanation: Electrowinning involves passing an electric current through a liquid electrolyte containing dissolved metal salts. The positive metal ions are reduced and deposited onto a cathode, recovering the primary metal directly from the solution.

61. B

Explanation: By definition, an orthogonal matrix Q satisfies $Q^TQ = I$. Taking the determinant of both sides gives $\det(Q^T)\det(Q) = \det(I) = 1$. Since $\det(Q^T) = \det(Q)$, we have $(\det(Q))^2 = 1$, so $\det(Q) = \pm 1$.

62. B

Explanation: For independent events, $P(A \cap B) = P(A)P(B) = 0.6 imes 0.5 = 0.3$. Using the addition rule: $P(A \cup B) = P(A) + P(B) - P(A \cap B) = 0.6 + 0.5 - 0.3 = 0.8$.

63. C

Explanation: Applying L'Hôpital's rule twice: the first derivative yields $(\sin x)/2x$. The second derivative yields $(\cos x)/2$. Evaluating at $x = 0$ gives $1/2$.

64. C

Explanation: A fundamental identity in vector calculus states that the divergence of the curl of any vector field is exactly zero ($abla \cdot (abla imes \mathbf{F}) = 0$).

65. A

Explanation: The standard formula for the Laplace transform of t^n is $L\{t^n\} = \int_0^\infty t^n e^{-st} dt = n!/s^{n+1}$, provided $s > 0$.

66. B

Explanation: If λ is an eigenvalue of A with eigenvector v, then $A^2v = A(Av) = A(\lambda v) = \lambda(Av) = \lambda^2 v$. Therefore, the eigenvalues of A^2 are the squares of the eigenvalues of A (4 and 9).

67. B

Explanation: This non-linear first-order differential equation is the standard form of a Bernoulli equation. It can be transformed into a linear differential equation by substituting $v = y^{1-n}$.

68. C

Explanation: The area is the definite integral of $\sin x$ from 0 to π: $\int_0^\pi \sin x dx = [-\cos x]_0^\pi = (-\cos \pi) - (-\cos 0) = -(-1) - (-1) = 2$.

69. C
Explanation: Euler's method is the simplest single-step numerical method for solving ODEs. It calculates the next value using the tangent line (slope) evaluated precisely at the current point: $y_{n+1} = y_n + h \cdot f(x_n, y_n)$.

70. C
Explanation: $f(z) = x^2 + y^2$. Here $u = x^2 + y^2, v = 0$. The Cauchy-Riemann equations ($u_x = v_y$ and $u_y = -v_x$) demand $2x = 0$ and $2y = 0$, which is only satisfied exactly at the origin $(x = 0, y = 0)$.

71. B
Explanation: The second row is exactly 3 times the first row. Because the rows are linearly dependent, there is only one independent row vector, making the rank of the matrix 1.

72. A
Explanation: There are 13 spades and 4 kings. One card is the King of Spades (intersection). Using the addition rule: $P(S \cup K) = P(S) + P(K) - P(S \cap K) = 13/52 + 4/52 - 1/52 = 16/52$ (or $4/13$).

73. C
Explanation: The directional derivative is the dot product $ablaf \cdot \mathbf{u}$. This product is maximized when the unit vector $\mathbf{u}$ points in the exact same direction as the gradient vector $ablaf$.

74. B
Explanation: The method uses the tangent line to find the next approximation. The correct standard formula is $x_{n+1} = x_n - f(x_n)/f'(x_n)$.

75. A
Explanation: First, evaluate the inner product: $\mathbf{j}imes\mathbf{k} = \mathbf{i}$. Next, evaluate the outer product: $\mathbf{i}imes\mathbf{i}$. The cross product of any vector with itself is the zero vector $\mathbf{0}$.

76. B
Explanation: The probability of the first ball being red is $5/8$. Without replacement, there are 4 red balls left out of 7 total. The probability of the second being red is $4/7$. Total probability $= (5/8)imes(4/7) = 20/56 = 5/14$.

77. C
Explanation: The characteristic equation is $r^2 + 9 = 0$, yielding purely imaginary roots $r = \pm 3i$. The general solution for imaginary roots is a linear combination of sine and cosine functions: $y = C_1 \sin(3x) + C_2 \cos(3x)$.

78. A
Explanation: For a pole of order m at $z = a$, the residue is calculated using the limit as zoa of the $(m-1)$-th derivative of $(z-a)^m f(z)$, divided by $(m-1)!$.

79. C
Explanation: An even function satisfies the condition $f(-x) = f(x)$. Since $\cos(-x) = \cos(x)$ for all x, the cosine function is an even function.

80. B
Explanation: With 1 interval, the endpoints are $a = 0, b = 2$. The trapezoidal rule formula is $(b-a)imes[f(a) + f(b)]/2$. Here, $2imes[0 + 2]/2 = 2$. (This is

exactly the area of the triangle).

81. B

Explanation: Replace letters with operators: $15times4 \div 2 + 6 - 3$. Apply BODMAS: Division first ($4 \div 2 = 2$). Then multiplication ($15times2 = 30$). Then addition/subtraction ($30 + 6 - 3 = 33$).

82. B

Explanation: E is the daughter of B. D is the brother of E, so D is the son of B. A is the brother of B. Therefore, A is the uncle of D, meaning D is the nephew of A.

83. B

Explanation: The series consists of the squares of consecutive natural numbers ($1^2, 2^2, 3^2, 4^2, 5^2, 6^2$). The next term is $7^2 = 49$.

84. A

Explanation: Net movement North = 10 - 6 = 4 km. Net movement East = 3 km. Using Pythagoras theorem, distance from start = $\sqrt{4^2 + 3^2} = \sqrt{16 + 9} = 5$ km. The direction is North-East.

85. C

Explanation: The 'engineers' circle sits entirely within the 'logical' circle. The 'scientists' circle intersects the 'logical' circle, but it is not forced to intersect the 'engineers' circle. The conclusion cannot be definitively determined.

86. C

Explanation: This is a direct substitution code where each letter maps to a specific symbol. M=F, E=G, R=I, C=E, U=C, R=I, Y=G. Therefore, C=E, U=C, R=I, E=G, spelling ECIG.

87. D

Explanation: Statement 1 gives a range. Statement 2 gives multiples of 50. Combining them, the temperature could be 1000°C, 1050°C, or 1100°C. Since there are still multiple possibilities, the exact temperature cannot be determined.

88. D

Explanation: Austenite, Cementite, and Ferrite are all microstructural phases found specifically within the iron-carbon (steel) metallurgical system. Bauxite is an ore of aluminum, making it the odd one out.

89. A

Explanation: Time from 5 AM day 1 to 10 PM day 4 is 89 hours. The faulty clock covers 23 hrs 44 min (23 + 11/15 = 356/15 hrs) in 24 true hours. True time for 89 faulty hours = $(24times15/356)times89$ = 90 hours. 5 AM + 90 hours = 11 PM on the 4th day.

90. B

Explanation: The word 'METALLURGICAL' has the letters: M, E, T, A, L(3), U, R, G, I, C. It does not contain the letter 'Y'. Therefore, the word 'ALLERGY' cannot be formed.