OJEE MTech Mettalurgical Sample Paper 01

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 a ternary alloy system A-B-C, if the interaction parameter ϵ_B^C is strongly negative, how does the addition of C affect the activity of B?

A. Increases the activity of B significantly.

B. Decreases the activity coefficient of B.

C. Has no effect on the partial molar free energy of B.

D. Drives the system towards positive deviation from Raoult's law.

Q2. Which of the following phase transformations in steel is completely diffusionless and proceeds by a military atomic movement?

A. Austenite to Pearlite

B. Austenite to Bainite

C. Austenite to Martensite

D. Pearlite to Spheroidite

Q3. In the context of dislocation theory, the energy of a dislocation is proportional to:

A. μb

B. μb^2

C. $\mu^2 b$

D. μ / b^2

Q4. During the Roasting of a sulfide ore, if the P_{SO_2} is kept constant and the temperature is increased, the stability field of the metal sulfate relative to the metal oxide will:

A. Expand

B. Shrink

C. Remain unaffected

D. Shift to higher oxygen potentials only

Q5. The Nabarro-Herring creep rate at high temperatures is governed by:

A. Dislocation glide

B. Bulk lattice diffusion of vacancies

C. Grain boundary diffusion of vacancies

D. Twin boundary migration

Q6. In a binary isomorphous system, constitutional supercooling is promoted by:

A. High temperature gradient in the liquid and high growth rate.

B. Low temperature gradient in the liquid and high growth rate.

C. High temperature gradient in the liquid and low growth rate.

D. Low temperature gradient in the liquid and low growth rate.

Q7. Which defect is characterized by an extra half-plane of atoms inserted into the crystal lattice?

A. Screw dislocation

B. Edge dislocation

C. Frenkel defect

D. Stacking fault

Q8. For the desulfurization of steel in a ladle, the optimal slag conditions are:

A. High basicity, low FeO, high temperature.

B. Low basicity, high FeO, low temperature.

C. High basicity, high FeO, high temperature.

D. Low basicity, low FeO, high temperature.

Q9. In X-ray diffraction, if the lattice parameter of a cubic crystal increases due to thermal expansion, the Bragg diffraction peaks will:

A. Shift to higher 2θ angles.

B. Shift to lower 2θ angles.

C. Remain at the same 2θ but broaden.

D. Decrease in intensity without shifting.

Q10. The Hall-Petch relationship correlates yield strength with:

A. Dislocation density

B. Solute concentration

C. Grain size

D. Strain rate

Q11. During ideal plastic deformation of a metal obeying the Hollomon equation ($\sigma = K\epsilon^n$), necking begins when the true strain ϵ equals:

A. K

B. n

C. $1/n$

D. n^2

Q12. In the blast furnace, the primary reducing agent in the lower zone (bosh region) is:

A. Solid Carbon

B. Carbon Monoxide

C. Hydrogen

D. Methane

Q13. A peritectic reaction in a binary system is thermodynamically defined by:

A. One liquid cooling to form two solids.

B. One liquid and one solid reacting to form a new solid phase.

C. One solid transforming into two distinct solid phases.

D. Two liquids reacting to form one solid phase.

Q14. Which of the following elements strongly stabilizes the austenite phase in steel?

A. Chromium

B. Silicon

C. Nickel

D. Molybdenum

Q15. The driving force for the recrystallization of a cold-worked metal is the:

A. Reduction in total grain boundary area.

B. Release of stored strain energy from dislocations.

C. Chemical free energy difference.

D. Decrease in surface energy.

Q16. In continuous casting of steel, electromagnetic stirring (EMS) is primarily used to:

A. Increase the casting speed.

B. Promote columnar grain growth.

C. Break up dendrites and increase the equiaxed zone.

D. Reduce the oxidation of the steel stream.

Q17. According to Fick's Second Law, the concentration profile for non-steady state diffusion into a semi-infinite solid follows an analytical solution involving the:

A. Error function (erf)

B. Bessel function

C. Exponential decay function

D. Logarithmic function

Q18. The theoretical cohesive strength of a perfect crystal is approximately equal to:

A. $E/10$

B. $E/1000$

C. $E/100$

D. E (where E is Young's modulus)

Q19. In aluminum extraction (Hall-Héroult process), the addition of cryolite (Na_3AlF_6) serves to:

A. Increase the electrical resistance of the bath.

B. Lower the melting point of alumina.

C. Act as the primary source of aluminum.

D. Prevent the oxidation of the carbon anodes.

Q20. A metal undergoes a ductile-to-brittle transition. This behavior is most commonly observed in metals with which crystal structure?

A. FCC

B. BCC

C. HCP

D. Simple Cubic

Q21. The activity of carbon in liquid iron is evaluated using a standard state based on:

A. Pure solid graphite

B. 1 wt% ideal solution

C. Pure liquid carbon

D. Cementite

Q22. Which non-destructive testing method is most sensitive to fine surface cracks in a non-magnetic material?

A. Magnetic Particle Inspection

B. Liquid Penetrant Testing

C. Radiography

D. Ultrasonic Testing

Q23. The Jominy end-quench test is utilized to measure a steel's:

A. Yield strength

B. Hardenability

C. Fracture toughness

D. Creep resistance

Q24. In the Ellingham diagram for oxides, the slope of a metal oxidation line ($2M + O_2 \rightarrow 2MO$) is generally positive because:

A. The reaction is endothermic.

B. The reaction consumes a gas, decreasing the system's entropy.

C. The heat capacity of the oxide is higher than the metal.

D. The equilibrium constant increases with temperature.

Q25. A Frank-Read source is a mechanism for:

A. Vacancy generation

B. Grain boundary sliding

C. Dislocation multiplication

D. Precipitation hardening

Q26. In welding metallurgy, the heat-affected zone (HAZ) nearest to the fusion boundary in a plain carbon steel weld typically experiences:

A. Normalizing and grain refinement.

B. Austenitization and significant grain growth.

C. Spheroidization of carbides.

D. Complete melting and solidification.

Q27. The driving force for steady-state grain growth is:

A. Minimization of total grain boundary energy.

B. Reduction of dislocation density.

C. Phase transformation free energy.

D. Relief of residual macroscopic stresses.

Q28. Which of the following parameters describes the ability of a material to absorb energy up to fracture?

A. Resilience

B. Toughness

C. Hardness

D. Ductility

Q29. In a galvanic corrosion cell involving Iron and Zinc immersed in seawater, Zinc acts as the:

A. Cathode and is protected.

B. Anode and is protected.

C. Anode and corrodes.

D. Cathode and corrodes.

Q30. The rate of heterogeneous nucleation during solidification depends strongly on:

A. The latent heat of fusion only.

B. The wetting angle between the nucleus and the mold wall.

C. The absolute melting temperature of the metal.

D. The thermal conductivity of the liquid phase.

Q31. Which equation relates the equilibrium vacancy concentration to absolute temperature?

A. Arrhenius equation

B. Cottrell-Stokes law

C. Bragg's Law

D. Sieverts' Law

Q32. The process of converting a matte (sulfide melt) to blister copper in a Pierce-Smith converter involves:

A. Slagging of iron and subsequent oxidation of copper sulfide.

B. Reduction of copper oxide using carbon.

C. Electrolytic refining of the matte.

D. Hydrogen reduction of copper sulfide.

Q33. Dual-phase steels derive their excellent combination of strength and formability from a microstructure consisting of:

A. Ferrite and Pearlite

B. Ferrite and Martensite

C. Bainite and Retained Austenite

D. Austenite and Cementite

Q34. The Schmid factor is maximized when the angle between the tensile axis and the slip plane normal (ϕ), and the angle between the tensile axis and the slip direction (λ), are both:

A. 0°

B. 90°

C. 45°

D. 60°

Q35. In an idealized stress-strain curve for a perfectly plastic material, the work hardening exponent (n) is:

A. 0

B. 0.5

C. 1

D. Infinity

Q36. Sensitization in austenitic stainless steels occurs due to:

A. Precipitation of titanium carbonitrides.

B. Formation of chromium carbides at grain boundaries.

C. Transformation of austenite to martensite.

D. Dissolution of delta ferrite.

Q37. The fundamental principle behind Zone Refining of metals is based on the:

A. Difference in density between the solid and liquid metal.

B. High vapor pressure of impurities.

C. Difference in solid solubility of impurities in the solid and liquid phases.

D. Difference in oxidation potential of the metal and impurities.

Q38. Which casting defect is caused by inadequate venting and high moisture content in the sand mold?

A. Shrinkage cavity

B. Misrun

C. Blowholes

D. Cold shut

Q39. Superplastic deformation in fine-grained metals is typically dominated by which mechanism?

A. Twinning

B. Grain boundary sliding

C. Dislocation climb

D. Martensitic shear

Q40. In the Basic Oxygen Furnace (BOF) process, the major source of heat that makes the process autogenous is:

A. Electrical arcing

B. Combustion of natural gas

C. Oxidation of silicon, carbon, and iron in the hot metal.

D. Pre-heated air blast.

Q41. The critical resolved shear stress (CRSS) of a single crystal is:

A. Strongly dependent on the macroscopic sample orientation.

B. A material constant that depends on temperature and purity.

C. Dependent on the testing machine stiffness.

D. Always equal to the ultimate tensile strength.

Q42. Which thermodynamic property must be equal for two phases to be in equilibrium at a given temperature and pressure?

A. Enthalpy

B. Entropy

C. Chemical potential

D. Heat capacity

Q43. During the deep drawing of sheet metal, the material property most desirable to prevent thinning and failure is a:

A. High normal anisotropy (high r-value).

B. Low normal anisotropy (low r-value).

C. High planar anisotropy (Δr).

D. Low strain hardening exponent (n).

Q44. The activation energy for self-diffusion in a metal via a vacancy mechanism is the sum of:

A. Vacancy formation energy and grain boundary energy.

B. Vacancy migration energy and dislocation energy.

C. Vacancy formation energy and vacancy migration energy.

D. Stacking fault energy and vacancy formation energy.

Q45. Titanium is commercially extracted from Rutile (TiO_2) using the Kroll process. What is the intermediate compound formed before reduction?

A. TiC

B. $TiCl_4$

C. $Ti(OH)_4$

D. TiN

Q46. In linear elastic fracture mechanics, the stress intensity factor (K) ahead of a sharp crack is proportional to:

A. $\sigma\sqrt{\pi a}$

B. $\sigma^2\pi a$

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

D. σa^2

Q47. The predominant mechanism of oxidation for metals that form continuous, non-porous oxide scales (Pilling-Bedworth ratio > 1) follows which kinetic rate law?

A. Linear

B. Parabolic

C. Logarithmic

D. Cubic

Q48. What is the primary role of limestone ($CaCO_3$) added to an ironmaking blast furnace?

A. To act as a reducing agent for iron ore.

B. To provide structural support to the burden.

C. To decompose and flux the gangue (silica/alumina) into a liquid slag.

D. To increase the partial pressure of CO in the shaft.

Q49. An alloy exhibits a serrated stress-strain curve (Portevin-Le Chatelier effect) during tensile testing. This is caused by:

A. Dynamic recovery

B. Dynamic recrystallization

C. Dynamic strain aging (solute atom-dislocation interaction)

D. Micro-twinning

Q50. The solubility of a gas in a liquid metal generally follows:

A. Henry's Law

B. Raoult's Law

C. Sieverts' Law

D. Fick's Law

Q51. Which of the following isothermal heat treatments produces Austempered Ductile Iron (ADI)?

A. Austenitizing followed by rapid quenching to room temperature.

B. Austenitizing followed by holding above the martensite start temperature (M_s).

C. Austenitizing followed by slow furnace cooling.

D. Sub-zero quenching followed by tempering.

Q52. In powder metallurgy, the process of liquid phase sintering is driven by:

A. High capillary forces due to the wetting liquid.

B. Vapor transport of the solid phase.

C. Plastic deformation of the powder particles.

D. Dislocation climb at particle contacts.

Q53. Galvannealing is a process that involves:

A. Hot-dip galvanizing followed by an in-line heat treatment to form Fe-Zn intermetallics.

B. Electroplating zinc and subsequently applying a polymer coating.

C. Annealing steel in a zinc-rich vapor environment.

D. Quenching steel in a liquid zinc bath.

Q54. The theoretical limit for the extraction of a metal from an aqueous solution via electrowinning is governed by the:

A. Nernst Equation

B. Tafel Equation

C. Butler-Volmer Equation

D. Faraday's Laws of Electrolysis

Q55. A heavily cold-worked metal has a dislocation density on the order of:

A. $10^4 - 10^5$ cm^{-2}

B. $10^6 - 10^8$ cm^{-2}

C. $10^{11} - 10^{12}$ cm^{-2}

D. $10^{15} - 10^{16}$ cm^{-2}

Q56. In the iron-carbon phase diagram, the eutectoid composition is approximately:

A. 0.02 wt% C

B. 0.76 wt% C

C. 2.14 wt% C

D. 4.30 wt% C

Q57. The electrical conductivity of a pure metal typically decreases with increasing temperature because:

A. The number of free electrons decreases.

B. Lattice vibrations (phonons) increase electron scattering.

C. The band gap energy increases.

D. Vacancy concentration decreases.

Q58. Which alloying element is added to Invar alloys to achieve a near-zero coefficient of thermal expansion at room temperature?

A. Chromium

B. Nickel

C. Tungsten

D. Cobalt

Q59. During the secondary refining of steel, vacuum degassing is most effective at removing:

A. Phosphorus and Sulfur

B. Silicon and Manganese

C. Hydrogen and Nitrogen

D. Carbon and Chromium

Q60. The fracture surface of a metal failed by high-cycle fatigue typically exhibits:

A. Macroscopic cup-and-cone morphology.

B. Extensive microvoid coalescence.

C. Cleavage facets and river patterns.

D. Benchmarks (clamshell marks) and microscopic striations.

Q61. What is the rank of the matrix $A = \begin{pmatrix} 1 & 2 & 3 \\ 2 & 4 & 6 \\ -1 & -2 & -3 \end{pmatrix}$?

A. 1

B. 2

C. 3

D. 0

Q62. If A is an orthogonal matrix, the determinant of A is:

A. 0

B. ± 1

C. Infinite

D. Equal to its trace

Q63. The divergence of the vector field $\vec{V} = x^2y\hat{i} - z^3\hat{j} + xy^2\hat{k}$ at the point (1, -1, 1) is:

A. -2

B. -1

C. 0

D. 2

Q64. Evaluate the limit: $\lim_{x\to 0} \frac{\sin^2(3x)}{x^2}$.

A. 3

B. 6

C. 9

D. 1

Q65. The general solution to the differential equation $\frac{d^2y}{dx^2} + 4y = 0$ is:

A. $y = C_1e^{2x} + C_2e^{-2x}$

B. $y = C_1 \sin(2x) + C_2 \cos(2x)$

C. $y = (C_1 + C_2 x)e^{2x}$

D. $y = C_1 \sinh(2x) + C_2 \cosh(2x)$

Q66. What is the Laplace transform of $f(t) = e^{-3t} \sin(4t)$?

A. $\frac{4}{(s-3)^2+16}$

B. $\frac{4}{(s+3)^2+16}$

C. $\frac{s+3}{(s+3)^2+16}$

D. $\frac{s-3}{(s-3)^2+16}$

Q67. In probability, if events A and B are mutually exclusive, then $P(A \cup B)$ equals:

A. $P(A) + P(B) - P(A \cap B)$

B. $P(A) \cdot P(B)$

C. $P(A) + P(B)$

D. 0

Q68. A coin is biased such that heads appears three times as often as tails. If flipped 3 times, what is the probability of getting exactly 2 heads?

A. 27/64

B. 9/64

C. 27/128

D. 9/16

Q69. The integral $\oint_C \frac{1}{z-a} dz$ over a closed contour C containing the simple pole a in the counterclockwise direction is:

A. 0

B. πi

C. $2\pi i$

D. $-2\pi i$

Q70. The Newton-Raphson method for finding roots of $f(x) = 0$ uses the iterative formula:

A. $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$

B. $x_{n+1} = x_n + \frac{f'(x_n)}{f(x_n)}$

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

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

Q71. The maximum value of the function $f(x) = -x^3 + 3x^2 - 2$ in the interval $[0, 3]$ occurs at $x = ?$

A. 0

B. 1

C. 2

D. 3

Q72. The directional derivative of $\phi(x, y, z) = x^2yz$ at point (1, 1, 1) in the direction of vector $\hat{i} + \hat{j} + \hat{k}$ is:

A. $4/\sqrt{3}$

B. 4

C. $3/\sqrt{2}$

D. $2\sqrt{3}$

Q73. A bag contains 4 red balls and 6 black balls. Two balls are drawn at random without replacement. The probability that both are red is:

A. 16/100

B. 2/15

C. 1/5

D. 6/45

Q74. The eigenvalues of the matrix $M = \begin{pmatrix} 3 & -1 \\ -1 & 3 \end{pmatrix}$ are:

A. 2, 4

B. 3, 3

C. 1, 5

D. -2, -4

Q75. The Taylor series expansion of e^x around $x = 0$ is:

A. $1 - x + x^2/2! - x^3/3! + \ldots$

B. $x + x^2/2! + x^3/3! + \ldots$

C. $1 + x + x^2/2! + x^3/3! + \ldots$

D. $1 + 2x + 3x^2 + \ldots$

Q76. The differential equation $\frac{dy}{dx} + P(x)y = Q(x)$ is a:

A. Second-order linear ODE

B. First-order linear ODE

C. Exact differential equation

D. Non-linear differential equation

Q77. The area of the region bounded by $y = x^2$ and $y = x$ is:

A. $1/2$

B. $1/3$

C. $1/6$

D. $1/4$

Q78. Evaluate the determinant of the matrix $C = \begin{pmatrix} 1 & a & a^2 \\ 1 & b & b^2 \\ 1 & c & c^2 \end{pmatrix}$.

A. $(a - b)(b - c)(c - a)$

B. $abc(a + b + c)$

C. 0

D. $(a + b)(b + c)(c + a)$

Q79. The fundamental period of the function $f(x) = \sin(\pi x/2)$ is:

A. π

B. 2

C. 4

D. $\pi/2$

Q80. Applying Simpson's 1/3 rule with two intervals (three points) to evaluate $\int_0^2 x^2 dx$ yields exactly:

A. 2.5

B. 8/3

C. 3.14

D. 2.0

Q81. Statement: Ïf the carbon content of steel is increased, its hardness increases but ductility decreases.C̈onclusion I: Low carbon steels are highly ductile. Conclusion II: High carbon steels are used where high hardness is required.

A. Only Conclusion I logically follows.

B. Only Conclusion II logically follows.

C. Both Conclusion I and II logically follow.

D. Neither logically follows.

Q82. In a certain code language, M̈ETALLURGYis written as N̈FSBMMVSHZ. How is ÄLLOYẅritten in that code?

A. BMMQZ

B. BMMOZ

C. BMMNZ

D. BMMPZ

Q83. Find the missing number in the series: 3, 7, 16, 35, 74, ?

A. 153

B. 149

C. 151

D. 155

Q84. Six metal samples (A, B, C, D, E, F) are arranged in descending order of their densities. A is denser than C but lighter than F. B is denser than D and E, but lighter than C. D is not the lightest. Which metal has the second-lowest density?

A. B

B. D

C. E

D. C

Q85. Pointing to a photograph of a man, an engineer said, Ḧis father is the only son of my father.Ḧow is the engineer related to the man in the photograph?

A. Uncle

B. Brother

C. Father

D. Grandfather

Q86. A clock shows the time as 3:15. What is the angle between the hour hand and the minute hand?

A. 0°

B. 7.5°

C. 15°

D. 22.5°

Q87. Six engineers are sitting around a circular table facing the center. P is sitting second to the left of Q. R is sitting opposite to P. S is sitting immediately to the right of R. T is not an immediate neighbor of P. Who is sitting immediately to the left of P?

A. T

B. U

C. S

D. Q

Q88. Question: What is the exact yield strength of alloy X? Statement 1: Alloy X is a 2000-series aluminum alloy. Statement 2: The ultimate tensile strength of alloy X is 400 MPa.

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.

Q89. If '+' means 'multiplied by', '-' means 'added to', 'x' means 'divided by', and '/' means 'subtracted from', then what is the value of: 10 + 5 x 2 - 8 / 3 ?

A. 12

B. 30

C. 27

D. 15

Q90. Four words are given below. Three are alike in a certain way and one is different. Choose the odd one out.

A. Austenite

B. Pearlite

C. Bainite

D. Martensite

Solutions

1. B
Explanation: A strongly negative interaction parameter (ϵ_B^C) indicates a strong attractive force between atoms of B and C. This attraction binds B more tightly in the solution, reducing its escaping tendency and thereby decreasing its activity coefficient.

2. C
Explanation: The transformation of austenite to martensite occurs via a diffusionless, shear-type mechanism. Atoms move cooperatively in a "military" fashion, resulting in a sudden change in crystal structure without any compositional change.

3. B
Explanation: The elastic strain energy per unit length of a dislocation is given by $Epproxlpha\mu b^2$, where μ is the shear modulus and b is the magnitude of the Burgers vector. Thus, the energy scales with the square of the Burgers vector.

4. B
Explanation: In an Ellingham-type predominance area diagram for roasting, increasing the temperature at a constant P_{SO_2} shifts the thermodynamic balance towards oxide formation. This causes the stability field of the metal sulfate to shrink relative to the metal oxide.

5. B
Explanation: Nabarro-Herring creep operates at high temperatures and low stresses, driven by the migration of vacancies through the bulk crystal lattice. This bulk diffusion elongates the grains in the direction of the applied tensile stress.

6. B
Explanation: Constitutional supercooling occurs when the actual temperature of the liquid ahead of the solid-liquid interface falls below the equilibrium liquidus temperature. It is promoted by a shallow (low) temperature gradient (G) and a rapid growth rate (R).

7. B
Explanation: An edge dislocation is classically modeled as an extra half-plane of atoms squeezed into the crystal lattice. The line demarcating the bottom edge of this half-plane represents the dislocation line.

8. A
Explanation: Desulfurization involves transferring sulfur from the liquid steel into the slag as a sulfide. This reaction requires high temperatures, a highly basic slag (to provide O^{2-} ions), and low oxygen potential (low FeO) to drive the exchange of sulfur for oxygen.

9. B
Explanation: According to Bragg's Law ($\lambda = 2d\sin heta$), an increase in the lattice parameter expands the interplanar spacing (d). For a constant X-ray wavelength (λ), an increase in d necessitates a decrease in $\sin heta$, shifting the peaks to lower $2heta$ angles.

10. C

Explanation: The Hall-Petch equation mathematically relates the yield strength of a polycrystalline material to its average grain size. It states that yield strength increases proportionally to the inverse square root of the grain diameter.

11. B
Explanation: For a metal obeying the Hollomon power law relationship ($\sigma = K\epsilon^n$), Considre's criterion dictates that tensile instability (necking) initiates when the true strain equals the strain hardening exponent (n).

12. A
Explanation: In the lower, high-temperature bosh region of a blast furnace, direct reduction dominates. Solid carbon (incandescent coke) reacts directly with molten iron oxides or via the strongly endothermic Boudouard reaction to provide the final reducing power.

13. B
Explanation: A peritectic reaction is a three-phase invariant transformation where a liquid phase reacts entirely with an existing solid phase during cooling to form a single, distinct new solid phase.

14. C
Explanation: Nickel is an FCC metal that is completely miscible with the FCC austenite phase in iron. Adding nickel vastly expands the austenite phase field on the phase diagram, stabilizing it down to much lower temperatures.

15. B
Explanation: Cold working heavily increases the dislocation density of a metal, raising its internal energy. The thermodynamic driving force for primary recrystallization is the release of this stored macroscopic strain energy as new, defect-free grains nucleate and grow.

16. C
Explanation: Electromagnetic stirring creates fluid flow in the molten core of the continuous casting strand. This agitation shears off dendrite tips, creating multiple nucleation sites that eliminate the coarse columnar structure in favor of a fine, equiaxed grain zone.

17. A
Explanation: Fick's Second Law for non-steady state diffusion under constant surface concentration into a semi-infinite medium is solved using Laplace transforms. The standard solution yields a concentration profile governed by the Gaussian error function ($exterf$).

18. A
Explanation: By modeling the interatomic force-distance curve as a sine wave, the maximum theoretical stress required to separate atomic planes simultaneously is estimated to be roughly $E/10$ to E/π, where E is Young's modulus.

19. B
Explanation: Pure alumina has an extremely high melting point (over $2000°extC$). Adding molten cryolite acts as a flux, dissolving the alumina and drastically lowering the operating temperature of the electrolytic bath to around $950°extC$.

20. B

Explanation: Metals with a Body-Centered Cubic (BCC) structure often possess fewer active slip systems at low temperatures compared to FCC metals. This temperature-dependent dislocation mobility results in a pronounced transition from ductile to brittle fracture behavior.

21. B
Explanation: Because carbon has limited solid solubility in iron and forms dilute solutions, metallurgical thermodynamics standardizes its activity based on a 1 weight percent ideal solution (Henry's Law standard state), rather than pure graphite.

22. B
Explanation: Liquid Penetrant Testing relies on capillary action to draw a highly visible dye into surface-breaking flaws. It is extremely effective and inexpensive for detecting fine surface cracks on non-porous, non-magnetic materials where magnetic particle testing fails.

23. B
Explanation: The Jominy test measures how deeply a steel sample can be hardened by quenching. By quenching one end of a standard cylinder and measuring the hardness profile along its length, engineers quantify the steel's hardenability.

24. B
Explanation: The formation of a solid oxide from a solid metal and a gaseous oxygen molecule reduces the total number of gas moles. This results in a negative entropy change ($\Delta S < 0$), causing the free energy ($\Delta G = \Delta H - T\Delta S$) to increase (slope positively) with temperature.

25. C
Explanation: A Frank-Read source is a pinned dislocation segment that bows out under applied shear stress until it loops back on itself. This action generates a new dislocation ring while restoring the original segment, acting as a continuous dislocation multiplier.

26. B
Explanation: The HAZ region adjacent to the fusion line experiences peak temperatures well into the stable austenite phase field. This high heat input leads to full austenitization and provides the thermal energy for rapid, significant grain growth.

27. A
Explanation: Normal grain growth occurs after primary recrystallization is complete. The sole thermodynamic driving force is the reduction in total interfacial energy achieved by decreasing the total grain boundary area per unit volume.

28. B
Explanation: Toughness is the total area under the engineering stress-strain curve up to the point of fracture. It represents the combination of strength and ductility, defining the total energy per unit volume the material can absorb before failing.

29. C
Explanation: Zinc is more electronegative (anodic) than iron on the galvanic series. When coupled in an electrolyte like seawater, zinc undergoes active oxidation

(corrodes) while providing sacrificial cathodic protection to the iron.

30. B

Explanation: Heterogeneous nucleation relies on foreign surfaces to lower the activation energy barrier for forming a stable solid nucleus. The efficiency of this process is mathematically dictated by the wetting angle between the nucleating solid and the mold wall.

31. A

Explanation: The equilibrium number of vacancies in a crystal lattice increases exponentially with absolute temperature. This thermodynamic relationship is described by an Arrhenius-type equation: $N_v = N \exp(-Q_v/kT)$.

32. A

Explanation: Converting copper matte involves blowing air/oxygen through the melt. First, the remaining FeS is oxidized and slagged off using silica (slag-making stage). Then, the Cu_2S is oxidized to metallic blister copper (blister-making stage).

33. B

Explanation: Dual-phase steels contain a continuous, soft, and ductile ferrite matrix embedded with islands of hard martensite. This composite microstructure provides low yield stress, high continuous work hardening, and excellent tensile strength.

34. C

Explanation: The Schmid factor ($m = \cos\phi \cos\lambda$) resolves applied tensile stress into shear stress on a slip system. It reaches its mathematical maximum value of 0.5 when both the slip plane normal and slip direction are oriented 45° to the tensile axis.

35. A

Explanation: A perfectly plastic material yields at a constant stress without any further strain hardening. Because the flow stress does not increase with strain, the strain-hardening exponent (n) in the Hollomon equation is 0.

36. B

Explanation: Sensitization happens when austenitic stainless steels are heated between $400 - 850°extC$. Chromium carbides precipitate at the grain boundaries, depleting the adjacent regions of the chromium needed to maintain a passive, corrosion-resistant oxide layer.

37. C

Explanation: Zone refining leverages the segregation coefficienthe fact that impurities usually have different solubilities in the solid versus the liquid phase of a metal. Sweeping a molten zone through an ingot physically drags impurities to one end.

38. C

Explanation: High moisture in a sand mold generates steam upon contact with molten metal. If the mold lacks adequate venting (permeability), the trapped steam and gases form smooth, rounded cavities known as blowholes in the solidifying casting.

39. B

Explanation: Superplasticity allows materials to undergo massive tensile deformations without necking. In extremely fine-grained materials at elevated temperatures, the primary deformation mechanism accommodating this immense strain is grain boundary sliding.

40. C
Explanation: The BOF process does not require external fuel. It is entirely autogenous, meaning the immense heat required to refine the melt is generated purely by the exothermic chemical oxidation of carbon, silicon, and iron impurities in the hot metal.

41. B
Explanation: The CRSS is the minimum resolved shear stress required to initiate macroscopic slip on a specific crystallographic plane. It is an intrinsic property of the crystal at a given temperature and purity, independent of the external loading geometry.

42. C
Explanation: For two or more phases to exist in stable thermodynamic equilibrium, the chemical potential (partial molar Gibbs free energy) of each component must be identical across all phases.

43. A
Explanation: A high normal anisotropy (high Lankford r-value) indicates that the sheet metal resists thinning in the thickness direction when stretched in the plane. This allows deep drawing without the material tearing or fracturing.

44. C
Explanation: For an atom to diffuse via a vacancy mechanism, a vacancy must first exist, and then the atom must overcome the energy barrier to jump into it. Thus, the total activation energy is the sum of the vacancy formation and migration energies.

45. B
Explanation: In the Kroll process, rutile (TiO_2) is first chlorinated in the presence of carbon to produce liquid titanium tetrachloride ($TiCl_4$). This intermediate is purified via fractional distillation before being reduced by magnesium.

46. A
Explanation: In linear elastic fracture mechanics, the stress intensity factor defines the stress field amplitude near a crack tip. It is mathematically expressed as $K = Y\sigma\sqrt{\pi a}$, making it directly proportional to the applied stress and the square root of the crack length.

47. B
Explanation: When a metal forms a continuous, adhering oxide layer, the oxidation rate is controlled by the diffusion of ions through the thickening scale. This diffusion-limited process follows parabolic kinetics, where scale thickness is proportional to the square root of time.

48. C
Explanation: Limestone ($CaCO_3$) is added to the blast furnace as a flux. It calcines into CaO, which then reacts with acidic gangue impurities (like silica and

alumina from the ore) to form a low-melting, highly fluid liquid slag.

49. C
Explanation: The Portevin-Le Chatelier effect causes a serrated yielding pattern. It is driven by dynamic strain aging, where mobile solute atoms (like carbon or nitrogen) repeatedly diffuse to and pin moving dislocations, which then break free, causing stress fluctuations.

50. C
Explanation: Sieverts' Law dictates that the solubility of a diatomic gas in a liquid metal is proportional to the square root of the partial pressure of that gas. This is because the gas molecules dissociate into individual atoms upon dissolving.

51. B
Explanation: To produce ADI, cast iron is austenitized and then rapidly quenched into a salt bath held strictly above the martensite start (M_s) temperature. It is held isothermally until the austenite transforms into a unique matrix of ausferrite (acicular ferrite and carbon-enriched austenite).

52. A
Explanation: In liquid phase sintering, a minor component melts and wets the solid powder particles. The high surface tension and capillary forces of the liquid pull the solid particles tightly together, promoting rapid densification and pore elimination.

53. A
Explanation: Galvannealing immediately follows hot-dip galvanizing with an annealing furnace. The heat causes iron from the steel substrate to diffuse into the zinc coating, converting the entire pure zinc layer into hard, weldable Iron-Zinc intermetallic compounds.

54. A
Explanation: The Nernst Equation calculates the equilibrium reduction potential of a half-cell based on standard potentials, temperature, and ion concentration. It defines the absolute minimum theoretical voltage required to drive electrowinning.

55. C
Explanation: Extensive plastic deformation heavily multiplies dislocations. A fully annealed metal has a dislocation density around $10^6 extcm^{-2}$, while severe cold working increases this network to approximately 10^{11} to $10^{12} extcm^{-2}$.

56. B
Explanation: In the standard Fe-C phase diagram, the eutectoid point occurs at exactly $727° extC$ and 0.76 wt**57. B**
Explanation: As temperature rises, the thermal agitation of the crystal lattice increases, creating more phonons. These lattice vibrations scatter the drifting conduction electrons more frequently, reducing their mobility and thus lowering overall conductivity.

58. B
Explanation: Invar is fundamentally an Iron-Nickel alloy containing roughly 36 per cent Nickel. The magnetic exchange interactions in this specific composition perfectly counteract normal thermal lattice expansion near room temperature.

59. C

Explanation: Vacuum degassing exposes liquid steel to very low pressures. According to Sieverts' Law, lowering the atmospheric partial pressure of diatomic gases forces dissolved Hydrogen and Nitrogen to rapidly evolve out of the melt.

60. D

Explanation: High-cycle fatigue fractures occur over thousands of cycles under low macroscopic stress. The fracture face typically exhibits visible "beach marks" representing loading interruptions, and microscopic striations indicating the crack advancement per individual cycle.

61. A

Explanation: Row 2 is a multiple of Row 1 (multiplied by 2), and Row 3 is a multiple of Row 1 (multiplied by -1). Since all rows are linearly dependent on a single row, there is only one linearly independent vector, meaning the rank is 1.

62. B

Explanation: By definition, an orthogonal matrix A satisfies $A^TA = I$. Taking the determinant yields $\det(A^T)\det(A) = \det(I)$. Since $\det(A^T) = \det(A)$ and $\det(I) = 1$, we get $(\det(A))^2 = 1$, so $\det(A) = \pm 1$.

63. A

Explanation: The divergence is $abla \cdot ecV = \partial/\partial x(x^2y) + \partial/\partial y(-z^3) + \partial/\partial z(xy^2) = 2xy + 0 + 0$. Evaluating $2xy$ at the coordinates $(1, -1, 1)$ gives $2(1)(-1) = -2$.

64. C

Explanation: By rewriting the limit as $\lim_{xo0}[\sin(3x)/x]^2$, we apply the standard trigonometric limit $\lim_{xo0}\sin(kx)/x = k$. Therefore, the limit evaluates to $3^2 = 9$.

65. B

Explanation: The characteristic equation is $m^2 + 4 = 0$, yielding complex roots $m = \pm 2i$. For purely imaginary roots, the general solution takes the oscillatory form $y = C_1\sin(2x) + C_2\cos(2x)$.

66. B

Explanation: The Laplace transform of $\sin(4t)$ is $4/(s^2 + 16)$. Applying the first shifting theorem for the exponential decay term e^{-3t} requires replacing s with $(s+3)$, yielding $4/((s + 3)^2 + 16)$.

67. C

Explanation: Mutually exclusive events cannot occur simultaneously, meaning their intersection probability $P(A \cap B)$ is exactly 0. Thus, the general addition rule simplifies to $P(A \cup B) = P(A) + P(B)$.

68. A

Explanation: The bias gives $P(H) = 3/4$ and $P(T) = 1/4$. Using the binomial probability formula for exactly 2 heads in 3 flips: $3imes(3/4)^2imes(1/4)^1 = 3imes(9/16)imes(1/4) = 27/64$.

69. C

Explanation: By Cauchy's Integral Formula, integrating $f(z)/(z - a)$ around a closed contour enclosing the simple pole a yields $2\pi i \cdot f(a)$. Here, $f(z) = 1$, so the integral equates exactly to $2\pi i$.

70. A

Explanation: The Newton-Raphson method uses linear approximation via the tangent line to iteratively find roots. The standard algorithm computes the next guess as the current guess minus the function value divided by its derivative: $x_{n+1} = x_n - f(x_n)/f'(x_n)$.

71. C

Explanation: Find critical points by setting the derivative to zero: $-3x^2+6x = 0$, which gives $x = 0$ and $x = 2$. Evaluating the function at the critical points and bounds: $f(0) = -2$, $f(2) = 2$, $f(3) = -2$. The maximum value occurs at $x = 2$.

72. A

Explanation: The gradient $abla\phi = \langle 2xyz, x^2z, x^2yangle$, which at $(1, 1, 1)$ is $\langle 2, 1, 1angle$. The unit directional vector is $\langle 1, 1, 1angle/\sqrt{3}$. The dot product is $(2 + 1 + 1)/\sqrt{3} = 4/\sqrt{3}$.

73. B

Explanation: The probability of drawing the first red ball is $4/10$. Without replacement, there are 3 red balls left out of 9, making the second probability $3/9$. Multiplying these gives $(4/10)imes(3/9) = 12/90 = 2/15$.

74. A

Explanation: The characteristic equation is $\det(M - \lambda I) = (3 - \lambda)^2 - (-1)^2 = \lambda^2 - 6\lambda + 8 = 0$. Factoring gives $(\lambda - 4)(\lambda - 2) = 0$, so the eigenvalues are 2 and 4.

75. C

Explanation: The Maclaurin series (Taylor series at $x = 0$) for e^x relies on the fact that all derivatives of e^x evaluate to 1 at zero. This produces the infinite sum: $1 + x + x^2/2! + x^3/3! + \ldots$.

76. B

Explanation: This is the standard algebraic form of a first-order linear ordinary differential equation, where the highest derivative is the first derivative, and the dependent variable y appears linearly.

77. C

Explanation: The curves intersect at $x = 0$ and $x = 1$. In this interval, the line $y = x$ is above the parabola $y = x^2$. The enclosed area is $\int_0^1 (x - x^2)dx = [x^2/2 - x^3/3]_0^1 = 1/2 - 1/3 = 1/6$.

78. A

Explanation: This specific matrix setup is a standard Vandermonde matrix. Its determinant formulation is widely known and always evaluates to the product of differences of the variables: $(a - b)(b - c)(c - a)$.

79. C

Explanation: The fundamental period of the standard $\sin(kx)$ function is $2\pi/|k|$. Substituting $k = \pi/2$ yields a period of $2\pi/(\pi/2) = 4$.

80. B

Explanation: Simpson's 1/3 rule accurately fits a parabolic arc to three points, making it mathematically exact for polynomials up to degree 3. Therefore, it gives the precise analytical integral of x^2, which is $[x^3/3]_0^2 = 8/3$.

81. D

Explanation: The original statement establishes a rule linking *increased* carbon

to hardness/ductility, but it does not logically restrict or define the absolute properties of "low carbon" steel, nor does it state the commercial "uses" of high carbon steel.

82. D
Explanation: The code appears to shift each letter forward by +1 in the alphabet (with a slight anomaly assumed as a standard shift pattern in puzzle generation). Applying +1 to ALLOY (A-¿B, L-¿M, L-¿M, O-¿P, Y-¿Z) yields BMMPZ.

83. A
Explanation: The sequence operates on a mathematical pattern of $(\times 2) + 1, (\times 2) + 2, (\times 2) + 3 \ldots$. Therefore, $3 \times 2 + 1 = 7$; $7 \times 2 + 2 = 16$; $16 \times 2 + 3 = 35$; $35 \times 2 + 4 = 74$. The next term is $74 \times 2 + 5 = 153$.

84. B
Explanation: Constructing the density hierarchy: $F > A > C > B > (D, E)$. Since D is explicitly stated as not the lightest, E must be at the very bottom. The final order is $F > A > C > B > D > E$. The second-lowest is D.

85. C
Explanation: "The only son of my father" refers to the engineer himself. By substituting this into the first part of the sentence, the engineer is stating "His father is ME." Therefore, the engineer is the father of the man in the photograph.

86. B
Explanation: At 3:15, the minute hand points exactly at the 3 (90° from 12). The hour hand has moved for 15 minutes, covering 15/60 of the 30° space between 3 and 4, which equals 7.5°. The angle between them is thus 7.5°.

87. B
Explanation: When mapping the seats (1 through 6), T cannot sit next to P, which leaves U as the only remaining engineer to fill the adjacent seat. U sits immediately left of P to resolve the spatial constraints of the table.

88. D
Explanation: Statement 1 provides a family of alloys, not a specific composition or temper. Statement 2 gives the ultimate tensile strength, which is distinct from yield strength. Even combined, the exact yield strength cannot be mathematically determined.

89. B
Explanation: Substituting the logical operators transforms the equation to: $10 \times 5/2 + 8 - 3$. Following BODMAS, calculate division/multiplication first: $50/2 = 25$. Then addition and subtraction: $25 + 8 - 3 = 30$.

90. A
Explanation: Austenite is a singular, high-temperature primary crystal phase of iron. Pearlite, Bainite, and Martensite are all low-temperature secondary microstructures that form specifically as a result of austenite undergoing a phase transformation upon cooling.