

PRACTICE EXAM 20: PE METALLURGICAL AND MATERIALS SIMULATION (100 QUESTIONS)

This practice exam contains 100 original questions scaled from the current NCEES PE Metallurgical and Materials blueprint. The official examination contains 85 questions within an 8.5-hour testing period. Use the NCEES electronic reference handbook conventions and both SI and U.S. Customary units as applicable. NCEES does not publish a numerical passing score.

1. A design-review team must identify the most defensible response: Which bond type chiefly explains the high electrical conductivity and nondirectional deformation behavior of most metals?

- A. Ionic bonding
- B. Covalent network bonding
- C. Hydrogen bonding
- D. Metallic bonding

2. For this metallurgical investigation, determine the correct conclusion: Cross-linking a thermosetting polymer generally has which effect?

- A. Makes it readily remeltable and recyclable
- B. Eliminates its glass-transition behavior
- C. Raises rigidity and prevents remelting by ordinary heating
- D. Converts all chains into linear molecules

3. During production troubleshooting, select the best technical answer: A low-angle grain boundary can be modeled most directly as what?

- A. An ordered array of dislocations
- B. A layer of amorphous liquid

- C. A single coherent precipitate
- D. A vacancy-free perfect crystal

4. An engineer assessing service performance asks: Which crystal structure has the highest atomic packing factor among the choices?

- A. Body-centered cubic
- B. Face-centered cubic
- C. Simple cubic
- D. Diamond cubic

5. Based on the controlling materials-science principle, For substitutional solid-solution formation, the Hume-Rothery rules favor solute and solvent atoms having which relationship?

- A. Opposite crystal structures at all temperatures
- B. Large electronegativity differences
- C. Atomic radii differing by less than about 15 percent
- D. Completely different valence states

6. A design-review team must identify the most defensible response: An edge dislocation is characterized by which feature?

- A. A helical lattice ramp parallel to its line
- B. An extra half-plane of atoms ending inside the crystal
- C. A coherent twin boundary only
- D. A vacancy cluster without lattice distortion

7. For this metallurgical investigation, determine the correct conclusion: In a BCC metal, the Burgers vector for a perfect dislocation is commonly of which type?

- A. $a/2\langle 111 \rangle$

- B. $a/2\langle 110 \rangle$
- C. $a\langle 100 \rangle$
- D. $a/3\langle 112 \rangle$

8. During production troubleshooting, select the best technical answer: Fick's first law describes diffusion under which condition?

- A. Transient diffusion with changing concentration
- B. Convection controlled by fluid velocity
- C. Grain growth controlled by curvature
- D. Steady state with flux proportional to the concentration gradient

9. An engineer assessing service performance asks: Increasing temperature generally accelerates substitutional diffusion because it does what?

- A. Increases vacancy concentration and atomic jump frequency
- B. Eliminates all lattice defects
- C. Reduces atomic vibration amplitude
- D. Makes the activation energy zero

10. Based on the controlling materials-science principle, During homogeneous nucleation, the critical nucleus forms when which energy balance is reached?

- A. Surface energy becomes exactly zero
- B. Diffusion stops at the interface
- C. Elastic modulus equals yield strength
- D. The decrease in bulk free energy overcomes the surface-energy penalty

11. A design-review team must identify the most defensible response: In a binary eutectic reaction on cooling, one liquid transforms into what?

- A. One solid solution only
- B. Two solid phases simultaneously
- C. A liquid plus one solid
- D. A gas and one solid

12. For this metallurgical investigation, determine the correct conclusion: What does the lever rule determine in a two-phase region of a binary phase diagram?

- A. The crystal structure of each phase
- B. The diffusion coefficient
- C. The relative amounts of the two equilibrium phases
- D. The nucleation rate

13. During production troubleshooting, select the best technical answer: A hypoeutectoid steel slowly cooled below the eutectoid temperature contains which constituents?

- A. Proeutectoid cementite and pearlite
- B. Proeutectoid ferrite and pearlite
- C. Martensite and retained austenite
- D. Bainite and spheroidite only

14. An engineer assessing service performance asks: Rapidly quenching austenitic steel below the martensite-start temperature produces martensite primarily by what mechanism?

- A. Long-range carbon diffusion
- B. Liquid-state solidification
- C. Recrystallization of ferrite
- D. A diffusionless shear transformation

15. Based on the controlling materials-science principle, Tempering quenched martensitic steel primarily accomplishes which result?

- A. Restores fully austenitic structure at room temperature
- B. Dissolves all carbides permanently
- C. Reduces brittleness while retaining useful strength
- D. Increases residual stress and hardness only

16. A design-review team must identify the most defensible response: A transgranular cleavage fracture surface is most likely to show which microscopic feature?

- A. River patterns crossing grains
- B. Equiaxed dimples only
- C. Intergranular facets following boundaries
- D. Beach marks from cyclic growth only

17. For this metallurgical investigation, determine the correct conclusion: Fatigue beach marks on a fracture surface indicate what?

- A. Single-event brittle cleavage only
- B. Uniform plastic yielding before fracture
- C. Changes or interruptions in crack-growth history
- D. Chemical segregation during casting

18. During production troubleshooting, select the best technical answer: For linear-elastic fracture mechanics, unstable crack growth begins when what occurs?

- A. Nominal stress reaches the elastic modulus
- B. The stress-intensity factor reaches the applicable fracture toughness
- C. Crack length becomes exactly one millimeter
- D. Poisson's ratio reaches one-half

19. An engineer assessing service performance asks: Plane-strain fracture toughness is generally lower than plane-stress toughness because plane strain has what?

- A. Greater crack-tip constraint and triaxiality
- B. No crack-tip stress field
- C. Unlimited through-thickness yielding
- D. Zero hydrostatic stress

20. Based on the controlling materials-science principle, Charpy impact testing of ferritic steel is especially useful for identifying what?

- A. The exact elastic modulus
- B. The equilibrium phase fractions
- C. The diffusion coefficient of carbon
- D. The ductile-to-brittle transition temperature

21. A design-review team must identify the most defensible response: Abrasive wear occurs primarily when what happens?

- A. Two clean metals weld locally and tear
- B. A liquid repeatedly collapses vapor bubbles
- C. Cyclic contact creates subsurface fatigue only
- D. Hard asperities or particles plow and cut a softer surface

22. For this metallurgical investigation, determine the correct conclusion: Adhesive wear and galling are promoted most strongly by which condition?

- A. Similar clean metals sliding under high contact stress
- B. Hard particles suspended between surfaces
- C. A thick stable lubricant film
- D. Noncontacting surfaces in vacuum isolation

23. During production troubleshooting, select the best technical answer: Elastohydrodynamic lubrication is associated most closely with what contacts?

- A. Stationary dry ceramic surfaces
- B. Highly loaded rolling contacts with elastic deformation
- C. Open reservoirs without relative motion
- D. Low-pressure gas diffusion through polymers

24. An engineer assessing service performance asks: A control chart point beyond a statistically established control limit most directly suggests what?

- A. The product automatically meets specification
- B. The process mean is exactly on target
- C. A special cause may be affecting the process
- D. All future measurements will be identical

25. Based on the controlling materials-science principle, A high process capability index requires what relationship?

- A. Control limits wider than all specifications
- B. Process spread small relative to specification width
- C. A large standard deviation by design
- D. The mean placed outside both limits

26. A design-review team must identify the most defensible response: Liquid penetrant testing is best suited to detecting which discontinuities?

- A. Deep internal flaws in thick steel
- B. Volumetric density changes only
- C. Surface-breaking flaws in nonporous materials
- D. Subsurface defects in porous concrete

27. For this metallurgical investigation, determine the correct conclusion: Magnetic-particle inspection can detect flaws in which materials?

- A. Ferromagnetic materials near the surface
- B. All polymers regardless of filler
- C. Austenitic stainless steels universally
- D. Nonmagnetic aluminum only

28. During production troubleshooting, select the best technical answer: Ultrasonic pulse-echo inspection locates an internal reflector primarily from what measurement?

- A. Surface color and gloss
- B. Magnetic permeability alone
- C. Electrical resistance of the couplant
- D. Sound travel time and wave velocity

29. An engineer assessing service performance asks: Radiographic testing is generally most sensitive to which flaw orientation?

- A. Any tight planar flaw perpendicular to the beam
- B. Surface roughness without thickness change
- C. Volumetric flaws or planar flaws aligned with the beam
- D. Residual stress with no density change

30. Based on the controlling materials-science principle, In failure analysis, preserving fracture surfaces before cleaning is essential because cleaning may do what?

- A. Destroy deposits, markings, and initiation evidence
- B. Increase the original crack length reproducibly
- C. Restore the component's service history
- D. Make every fracture surface identical

31. A design-review team must identify the most defensible response: A fishbone diagram in a failure investigation is used primarily to do what?

- A. Calculate fracture toughness directly
- B. Organize possible causes into logical categories
- C. Measure residual stress by diffraction
- D. Set heat-treatment temperatures

32. For this metallurgical investigation, determine the correct conclusion: Fitness-for-service assessment differs from simple code acceptance because it does what?

- A. Requires every detected flaw to be removed
- B. Ignores material toughness and loading
- C. Applies only before a component enters service
- D. Evaluates whether a known flaw is tolerable under actual service conditions

33. During production troubleshooting, select the best technical answer: For material selection using an Ashby chart, a performance index is used to do what?

- A. Replace all detailed design calculations
- B. Rank materials for a stated objective and constraints
- C. Identify chemical composition from a micrograph
- D. Determine process control limits

34. An engineer assessing service performance asks: Recycling aluminum generally saves substantial energy compared with primary production because it avoids what?

- A. Electrolytic reduction of alumina from ore
- B. All remelting and refining operations
- C. Any need for alloy sorting
- D. Formation of surface oxide films

35. Based on the controlling materials-science principle, A life-cycle assessment should define system boundaries before comparing materials because boundaries determine what?

- A. The crystal structure of each candidate
- B. The exact fatigue crack path
- C. Which processes and environmental burdens are included
- D. The equilibrium vacancy concentration

36. A design-review team must identify the most defensible response: Thermal shock resistance of a brittle ceramic is generally improved by which property combination?

- A. High expansion and low conductivity
- B. Low strength and high elastic modulus
- C. High porosity regardless of environment
- D. Low thermal expansion and high thermal conductivity

37. For this metallurgical investigation, determine the correct conclusion: Oxidation resistance of an alloy at high temperature is best when the scale is what?

- A. Porous, cracked, and rapidly growing
- B. Volatile at the service temperature
- C. Slow-growing, adherent, and continuous
- D. Nonprotective and repeatedly spalling

38. During production troubleshooting, select the best technical answer: A Pilling-Bedworth ratio near unity often favors protective oxidation because the oxide volume is what?

- A. Too small to cover the consumed metal
- B. Sufficient to cover the metal without excessive compressive stress
- C. Always large enough to cause immediate spallation
- D. Unrelated to the consumed metal volume

39. An engineer assessing service performance asks: Shot peening improves fatigue resistance mainly by introducing what?

- A. Compressive residual stress at the surface
- B. Tensile residual stress throughout the core
- C. A coarse annealed grain structure
- D. A thick brittle intermetallic layer

40. Based on the controlling materials-science principle, Uniform corrosion of carbon steel in an aerated neutral electrolyte is an example of what process?

- A. Purely mechanical erosion without electrochemistry
- B. Diffusionless phase transformation
- C. Radiation-induced embrittlement
- D. Coupled anodic metal dissolution and cathodic reduction

41. A design-review team must identify the most defensible response: For galvanically coupled metals in an electrolyte, which configuration most severely attacks the anodic metal?

- A. A large anode connected to a small cathode
- B. A small anode connected to a large cathode
- C. Equal areas isolated electrically
- D. Two cathodes with no electrolyte

42. For this metallurgical investigation, determine the correct conclusion: Passivity in stainless steel is primarily provided by which surface feature?

- A. A thick porous iron scale
- B. A deposited layer of elemental nickel only
- C. A thin, adherent chromium-rich oxide film
- D. Complete absence of surface oxygen

43. During production troubleshooting, select the best technical answer: Stress-corrosion cracking requires which combination?

- A. Compression alone in any dry atmosphere
- B. High hardness without an electrolyte
- C. Cyclic stress with no chemical interaction
- D. Tensile stress, a susceptible material, and a specific environment

44. An engineer assessing service performance asks: Hydrogen embrittlement most directly reduces which property of a high-strength steel?

- A. Ductility and fracture resistance
- B. Thermal conductivity only
- C. Elastic modulus to nearly zero
- D. Equilibrium melting temperature

45. Based on the controlling materials-science principle, A polymer exposed above its glass-transition temperature generally exhibits what change?

- A. Complete crystallization instantly
- B. Higher stiffness from frozen chain motion
- C. Greater segmental mobility and lower stiffness
- D. Conversion to a thermoset network

46. A design-review team must identify the most defensible response: Creep becomes a primary design concern when a component experiences what condition?

- A. A single brief load at low temperature
- B. Only hydrostatic compression at absolute zero
- C. Elastic unloading without time dependence
- D. Sustained stress at elevated homologous temperature

47. For this metallurgical investigation, determine the correct conclusion: During steady-state secondary creep, the strain rate is approximately what?

- A. Zero because deformation stops
- B. Constant because hardening and recovery balance
- C. Exponentially decreasing to zero
- D. Instantaneously infinite

48. During production troubleshooting, select the best technical answer: Which S-N curve feature defines fatigue endurance behavior?

- A. Stress amplitude plotted against cycles to failure
- B. Creep strain plotted against elapsed time
- C. Impact energy plotted against temperature
- D. Hardness plotted against indentation depth

49. An engineer assessing service performance asks: A component subjected to a mean stress plus alternating stress is commonly assessed using which relation?

- A. Goodman or Gerber mean-stress correction
- B. Fick diffusion relation
- C. Hall-Petch grain-size relation
- D. Bragg diffraction law

50. Based on the controlling materials-science principle, A hot tear in a casting forms primarily because of what condition?

- A. Excessive machining of a fully cooled and stress-relieved casting
- B. Uniform elastic contraction of the casting without any external restraint
- C. Restricted contraction while the alloy is weak near the end of solidification
- D. Complete absence of a freezing range during alloy solidification

51. A design-review team must identify the most defensible response: Gas porosity in an aluminum casting can be reduced by what action?

- A. Increasing dissolved hydrogen before pouring
- B. Degassing the melt and limiting moisture pickup
- C. Using wetter tools and refractories
- D. Holding the melt longer in humid air

52. For this metallurgical investigation, determine the correct conclusion: In arc welding steel, preheating a thick hardenable joint mainly reduces what risk?

- A. All weld-metal solidification shrinkage
- B. Loss of alloying elements by evaporation only
- C. Formation of any fusion zone
- D. Hydrogen-assisted cracking in the heat-affected zone

53. During production troubleshooting, select the best technical answer: A sensitized austenitic stainless steel is vulnerable to intergranular corrosion because of what?

- A. Nickel enrichment eliminates passivity in grain interiors
- B. Ferrite transforms completely to martensite
- C. Carbon dissolves all grain boundaries
- D. Chromium carbide precipitation depletes chromium near grain boundaries

54. An engineer assessing service performance asks: Brazing differs from fusion welding because brazing does what?

- A. Melts the base metals without filler
- B. Melts a filler metal while leaving base metals solid
- C. Uses no capillary action
- D. Always occurs below room temperature

55. Based on the controlling materials-science principle, Austempering steel is designed to produce predominantly which microstructure?

- A. Bainite
- B. Fresh untempered martensite
- C. Coarse pearlite only
- D. Proeutectoid cementite only

56. A design-review team must identify the most defensible response: Martempering reduces quench distortion by doing what?

- A. Transforming all austenite to pearlite during slow furnace cooling
- B. Eliminating the martensite transformation entirely
- C. Equalizing temperature before martensitic transformation proceeds through the section
- D. Holding above the austenitizing temperature

57. For this metallurgical investigation, determine the correct conclusion: Quench severity is highest for which medium under typical conditions?

- A. Agitated brine
- B. Still oil
- C. Still air
- D. Vacuum cooling

58. During production troubleshooting, select the best technical answer: Precipitation hardening achieves peak strength through what feature?

- A. Complete removal of solute atoms from the alloy
- B. Coarsened incoherent particles at maximum spacing
- C. A fine distribution of coherent or semicoherent precipitates that impedes dislocations
- D. Elimination of all lattice strain

59. An engineer assessing service performance asks: Carburizing a low-carbon steel component is used primarily to create what?

- A. A soft decarburized case throughout
- B. Uniform high carbon through a very thick section instantly
- C. A ceramic coating without diffusion
- D. A hard carbon-enriched case over a tough core

60. Based on the controlling materials-science principle, Nitriding can produce a hard case with relatively low distortion because it commonly does what?

- A. Requires melting the component surface
- B. Forms alloy nitrides below the steel transformation temperature
- C. Always requires a severe water quench
- D. Removes nitrogen from the surface

61. A design-review team must identify the most defensible response: During powder sintering, neck growth between particles is driven primarily by what?

- A. Reduction of total surface free energy
- B. Increase of total pore surface area
- C. Mechanical melting of every particle
- D. Creation of additional free surfaces

62. For this metallurgical investigation, determine the correct conclusion: Hot isostatic pressing improves a powder or casting by applying what?

- A. Uniaxial room-temperature tension only
- B. Localized arc heating without pressure
- C. Chemical etching under vacuum only
- D. High temperature and gas pressure uniformly in all directions

63. During production troubleshooting, select the best technical answer: Selective laser melting of metal powder requires control of energy density chiefly to avoid what tradeoff?

- A. Normal grain formation throughout any completely melted powder track
- B. Lack of fusion at low input and keyhole porosity at excessive input
- C. Ordinary solidification whenever a stable melt pool cools below liquidus
- D. All residual stress regardless of scan pattern or preheating strategy

64. An engineer assessing service performance asks: Fused-filament fabrication commonly produces anisotropic polymer parts because of what?

- A. Every layer is a single crystal
- B. Polymer chains cannot orient during extrusion
- C. Interlayer bonding differs from strength along deposited roads
- D. The nozzle applies equal pressure in all directions

65. Based on the controlling materials-science principle, A thermal-spray coating adheres to a roughened substrate mainly through what?

- A. Mechanical interlocking of flattened particles with the surface
- B. Equilibrium alloying through the full substrate thickness
- C. Complete melting of the base component
- D. Covalent bonding in every coating system

66. A design-review team must identify the most defensible response: Electroplating thickness on a cathodic workpiece is governed most directly by what variables?

- A. Elastic modulus and Poisson's ratio only
- B. Current, time, efficiency, and electrochemical equivalent
- C. Grain size without electrical current
- D. Atmospheric pressure alone

67. For this metallurgical investigation, determine the correct conclusion: Galvanizing protects steel even at small coating scratches because zinc does what?

- A. Becomes a noble cathode that accelerates iron loss
- B. Prevents all electrolyte contact at any damage
- C. Raises the steel melting point
- D. Acts as a sacrificial anode to exposed steel

68. During production troubleshooting, select the best technical answer: In adhesive bonding of polymers or composites, surface preparation primarily improves what?

- A. Bulk elastic modulus of the adherend
- B. Fiber volume fraction throughout the laminate
- C. Wetting and interfacial adhesion
- D. Glass-transition temperature of the entire part

69. An engineer assessing service performance asks: Differential scanning calorimetry measures what during a programmed temperature change?

- A. Crystal orientation from diffraction spots
- B. Heat-flow difference associated with thermal transitions
- C. Surface topography from electron emission
- D. Elemental mass-to-charge ratios

70. Based on the controlling materials-science principle, Hot rolling is performed above the recrystallization temperature mainly to obtain what benefit?

- A. Large deformation without accumulating severe work hardening
- B. Maximum retained cold-work strength
- C. Complete suppression of oxidation
- D. Perfect dimensional tolerance without finishing

71. A design-review team must identify the most defensible response: Cold working a ductile metal generally causes which property change?

- A. Lower dislocation density and higher ductility
- B. Lower strength with no texture
- C. Higher strength and lower ductility
- D. Immediate recrystallization at room temperature

72. For this metallurgical investigation, determine the correct conclusion: During recovery of a cold-worked metal, which change occurs before recrystallization?

- A. New strain-free grains consume the structure completely
- B. All grain boundaries melt
- C. The alloy becomes amorphous
- D. Dislocations rearrange and residual stresses decrease

73. During production troubleshooting, select the best technical answer: Primary recrystallization is complete when what has occurred?

- A. All second-phase particles have dissolved
- B. The metal has transformed to liquid
- C. New strain-free grains have replaced the cold-worked matrix
- D. Grain growth has reduced boundary area to zero

74. An engineer assessing service performance asks: In sand casting, a riser is designed primarily to do what?

- A. Supply liquid metal to compensate for solidification shrinkage
- B. Filter all inclusions from the melt
- C. Increase mold hardness locally
- D. Vent only hydrogen from solid metal

75. Based on the controlling materials-science principle, Investment casting is selected when a component requires what?

- A. Only very large simple steel ingots
- B. The lowest-cost permanent mold for millions of parts
- C. Continuous sheet production
- D. Complex geometry with good surface finish and accuracy

76. A design-review team must identify the most defensible response: In injection molding, insufficient holding pressure most directly promotes which defect?

- A. Flash from excessive cavity pressure
- B. Sink marks and internal shrinkage voids
- C. Burning from trapped air only
- D. Weld strengthening at every flow front

77. For this metallurgical investigation, determine the correct conclusion: Transmission electron microscopy requires a very thin specimen primarily so that what can occur?

- A. Electrons transmit through the material
- B. Visible light reflects from an opaque surface
- C. Magnetic domains become permanently aligned
- D. The specimen remains at its melting point

78. During production troubleshooting, select the best technical answer: Electron backscatter diffraction is used chiefly to map what?

- A. Polymer molecular weight
- B. Bulk chemical composition with no diffraction
- C. Internal pressure in closed pores
- D. Crystallographic orientation and grain-boundary character

79. An engineer assessing service performance asks: Optical emission spectroscopy of a metal determines composition by analyzing what?

- A. Indentation depth under a known force
- B. Heat flow during melting
- C. Characteristic wavelengths emitted by excited atoms
- D. Sound travel time through the specimen

80. Based on the controlling materials-science principle, Thermogravimetric analysis records which quantity as temperature or time changes?

- A. Crystal orientation
- B. Specimen mass
- C. Elastic strain only
- D. Acoustic impedance

81. A design-review team must identify the most defensible response: Dynamic mechanical analysis of a polymer measures what response?

- A. Only static tensile strength at failure
- B. Storage modulus, loss modulus, and damping under oscillation
- C. Elemental composition by X-rays
- D. Grain orientation by diffraction

82. For this metallurgical investigation, determine the correct conclusion: A Rockwell hardness test determines hardness from what?

- A. Optical measurement of two diagonal lengths
- B. Rebound height of a dropped hammer only
- C. Energy absorbed in pendulum fracture
- D. Permanent indentation depth under specified minor and major loads

83. During production troubleshooting, select the best technical answer: The Vickers hardness number is calculated using what?

- A. Crack length divided by specimen width
- B. Rebound velocity divided by density
- C. Applied load divided by pyramidal indentation surface area
- D. Torque divided by polar moment only

84. An engineer assessing service performance asks: In a tensile test, the 0.2-percent offset method estimates what?

- A. Yield strength when no sharp yield point exists
- B. Ultimate strength after necking only
- C. Elastic modulus from fracture area
- D. Poisson's ratio from hardness

85. Based on the controlling materials-science principle, Engineering stress differs from true stress after necking because engineering stress uses what area?

- A. Instantaneous minimum area
- B. Fracture surface area only
- C. Elastic recovery area
- D. Original cross-sectional area

86. A design-review team must identify the most defensible response: A strain gauge aligned with the loading direction measures which quantity directly?

- A. Hydrostatic pressure only
- B. Normal strain along its grid axis
- C. Crystal lattice spacing without calibration
- D. Fracture toughness

87. For this metallurgical investigation, determine the correct conclusion: A three-element strain-gauge rosette is used when what is unknown?

- A. The specimen temperature is exactly constant
- B. Only one uniaxial strain component exists
- C. The principal strain directions at the surface
- D. The alloy chemical composition

88. During production troubleshooting, select the best technical answer: Fracture toughness testing requires a fatigue precrack primarily to provide what?

- A. A sharp, representative crack tip
- B. A blunt notch with a large radius
- C. Uniform plastic strain across the specimen
- D. A corrosion-free polished surface only

89. An engineer assessing service performance asks: In fatigue crack-growth testing, the Paris relation connects crack-growth rate with what?

- A. Elastic modulus alone
- B. Mean grain diameter only
- C. Absolute temperature only
- D. Stress-intensity-factor range

90. Based on the controlling materials-science principle, A corrosion polarization curve can provide an estimate of corrosion current density from what?

- A. The specimen's optical reflectivity
- B. Only the open-circuit potential value
- C. The intersection or extrapolation of anodic and cathodic behavior
- D. Grain size measured metallographically

91. A design-review team must identify the most defensible response: Salt-spray testing is best interpreted as what kind of test?

- A. A comparative accelerated exposure under specified conditions
- B. A universal predictor of exact field life
- C. A direct measurement of fracture toughness
- D. An equilibrium phase-diagram experiment

92. For this metallurgical investigation, determine the correct conclusion: Metallographic etching reveals microstructure mainly by what mechanism?

- A. Uniformly polishing every phase to identical reflectivity
- B. Selective chemical or electrochemical attack creates contrast
- C. Melting grain boundaries
- D. Increasing specimen thickness

93. During production troubleshooting, select the best technical answer: For quantitative metallography, the area fraction of a phase on a representative random plane estimates what?

- A. Its volume fraction in the material
- B. Its elastic modulus
- C. Its atomic packing factor
- D. Its diffusion activation energy

94. An engineer assessing service performance asks: The linear-intercept method estimates grain size by counting what?

- A. All atoms in a unit cell
- B. Diffraction peaks above background
- C. Grain-boundary intersections along test lines
- D. Hardness impressions per unit area

95. Based on the controlling materials-science principle, Archimedes' method determines bulk density from what measurements?

- A. Only specimen color and volume by inspection
- B. Mass in air and apparent mass while immersed
- C. Electrical resistance at two temperatures
- D. Indentation diagonal lengths

96. A design-review team must identify the most defensible response: A four-point electrical resistivity measurement reduces error from what?

- A. Thermal expansion of the specimen only
- B. Crystal diffraction from the surface
- C. Magnetic saturation only
- D. Lead and contact resistance

97. For this metallurgical investigation, determine the correct conclusion: X-ray diffraction identifies crystalline phases mainly through which relation?

- A. Hooke's law linking stress and strain
- B. Bragg's law linking wavelength, spacing, and diffraction angle
- C. Fick's law linking flux and concentration
- D. Faraday's law linking mass and charge

98. During production troubleshooting, select the best technical answer: Peak broadening in an X-ray diffraction pattern can indicate what?

- A. Only a perfectly strain-free single crystal
- B. Complete absence of crystalline material in every case
- C. Small crystallite size or microstrain
- D. A larger specimen mass only

99. An engineer assessing service performance asks: Scanning electron microscopy is especially useful for examining what?

- A. Bulk crystal structure without a surface
- B. Only molecular vibrations in liquids
- C. Neutron absorption through thick steel
- D. Surface morphology with large depth of field

100. Based on the controlling materials-science principle, In SEM-based energy-dispersive spectroscopy, characteristic X-rays reveal what?

- A. Elements present in the interaction volume
- B. Exact oxidation state in every compound
- C. Residual stress without calibration
- D. Polymer molecular weight distribution

Practice Exam 20: Answer Key and Explanations

1. D — Metallic bonding contains delocalized electrons and is relatively nondirectional. Electron mobility supports conductivity, while nondirectionality permits atomic planes to slide without breaking specific localized bonds. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

2. C — Covalent cross-links form a network that restricts chain motion and prevents viscous remelting. Heating may soften slightly or cause degradation, but does not produce normal thermoplastic flow. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

3. A — Small crystallographic misorientation is accommodated by a regular dislocation array. As misorientation grows, individual dislocation cores overlap and the simple low-angle description becomes less useful. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

4. B — FCC has an atomic packing factor of 0.74, exceeding BCC at about 0.68 and simple cubic at about 0.52. Diamond cubic is more open. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

5. C — Similar atomic size limits lattice strain. Similar structure, electronegativity, and valence also favor extensive solubility; the listed alternatives generally reduce it. Atomic arrangement, thermodynamics, and kinetics

determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

6. B — The termination of an extra half-plane creates an edge dislocation. Screw dislocations form a helical ramp, while twins and vacancy clusters are different defects. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

7. A — The shortest close-packed direction in BCC is the body diagonal, giving the common perfect-dislocation Burgers vector $a/2\langle 111 \rangle$. The other vectors correspond to different lattices or defects. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

8. D — Fick's first law applies when the concentration profile is steady. Flux is proportional to the negative concentration gradient; transient behavior instead requires Fick's second law. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

9. A — Thermal activation raises both the equilibrium vacancy population and the probability of successful atomic jumps. The activation energy remains finite, and lattice defects are not eliminated. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

10. D — A small embryo is penalized by new interfacial area, while transformation lowers bulk free energy. Above the critical radius, the bulk benefit dominates and growth becomes favorable. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

11. B — At the eutectic composition and temperature, liquid transforms isothermally into two distinct solid phases. Primary solid may form before the reaction for off-eutectic compositions. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

12. C — The lever rule uses tie-line segment lengths to calculate phase fractions at equilibrium. Phase compositions come from tie-line endpoints, not from the phase-fraction calculation itself. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

13. B — Below the eutectoid carbon content, ferrite forms before the eutectoid reaction; remaining austenite transforms to pearlite. Proeutectoid cementite occurs in hypereutectoid steel. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

14. D — Martensite forms by coordinated lattice shear without long-range diffusion. Carbon becomes trapped in a supersaturated body-centered tetragonal structure, producing high strength and internal stress. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing

choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

15. C — Tempering permits controlled carbon redistribution and carbide precipitation, relieving quench stresses and improving toughness. Strength usually decreases somewhat, but the hardness-toughness balance improves. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

16. A — Cleavage propagates through grains along crystallographic planes, producing facets and converging river patterns. Dimples indicate ductile rupture, while boundary facets indicate intergranular fracture. Atomic arrangement, thermodynamics, and kinetics determine which structural mechanism applies. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

17. C — Beach marks are macroscopic bands formed as a fatigue crack advances under changing service conditions or intermittent operation. They differ from microscopic striations, although both relate to progressive crack growth. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses.

18. B — Mode I instability is expected when K_I equals or exceeds the appropriate toughness under valid constraint conditions. Crack size, geometry, and applied stress jointly determine K_I . Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

19. A — Thick sections constrain through-thickness deformation, raising triaxiality and limiting plastic-zone development. This produces a conservative lower-bound toughness compared with thin, plane-stress specimens. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

20. D — Charpy absorbed energy versus temperature reveals the transition from ductile, high-energy behavior to brittle, low-energy behavior in many ferritic steels. It is comparative rather than a direct toughness measurement. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses.

21. D — Abrasive wear involves cutting or plowing by harder features. Adhesive wear involves junction formation and tearing, while cavitation and rolling-contact fatigue have different damage mechanisms. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

22. A — Intimate contact between mutually soluble or similar metals can form junctions that shear and transfer material. High load, poor lubrication, and roughness promote severe adhesive wear and galling. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

23. B — In gears and rolling bearings, pressure greatly increases lubricant viscosity while surfaces deform elastically, allowing a thin separating film. This coupled behavior defines elastohydrodynamic lubrication. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

24. C — Control limits describe expected common-cause variation. A point outside them signals potential instability requiring investigation; control limits are not the same as engineering specification limits. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

25. B — Capability improves when natural process variation occupies a small fraction of the allowable tolerance. Centering also matters for Cpk, which penalizes a shifted process mean. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

26. C — Penetrant enters flaws open to the surface by capillary action and is drawn out by developer. It cannot reveal sealed internal defects and is unreliable on porous surfaces. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

27. A — Magnetic-particle testing requires magnetization, so it is limited to ferromagnetic materials. Leakage fields at surface or shallow subsurface discontinuities attract particles and reveal indications. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

28. D — The time between transmitted and reflected ultrasonic pulses, combined with material wave speed, gives reflector depth. Signal amplitude and behavior provide additional information about size and orientation. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

29. C — Radiography responds to differences in radiation path length and attenuation. Volumetric voids are readily detected, while planar flaws are best seen when the beam travels along their plane. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

30. A — Deposits, corrosion products, rub marks, and fine topography may locate initiation or reveal the environment. Premature cleaning can irreversibly remove this evidence and compromise causal reconstruction. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

31. B — The cause-and-effect diagram structures hypotheses involving material, method, machine, measurement, environment, and people. It supports systematic investigation but does not itself prove root cause. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

32. D — Fitness-for-service combines flaw geometry, stresses, material properties, damage mechanism, and future growth to judge continued operation. It can support repair, rerating, monitoring, or replacement decisions. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

33. B — A performance index combines relevant properties according to the governing design objective, such as minimum mass at required stiffness. It screens and ranks candidates under explicit constraints. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

34. A — Primary aluminum production requires energy-intensive alumina refining and electrolysis. Secondary production mainly involves collection, sorting, remelting, and composition adjustment, so its energy demand is much lower. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

35. C — System boundaries decide whether extraction, manufacturing, transport, use, maintenance, recycling, and disposal are counted. Inconsistent boundaries can reverse an apparent environmental comparison. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

36. D — Low expansion reduces thermally induced strain, while high conductivity reduces temperature gradients. Strength, toughness, and a lower modulus can also improve resistance depending on geometry and heat-transfer conditions. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

37. C — A protective oxide limits transport of ions and oxygen, adheres during thermal cycling, and covers the substrate continuously. Porosity, volatility, cracking, or spallation exposes fresh metal. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

38. B — A ratio near unity allows the oxide to cover the substrate without being overly tensile from insufficient volume or highly compressive from excessive volume. It is a screening indicator, not a complete prediction. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses.

39. A — Surface fatigue cracks are driven by tensile stress. Shot peening plastically deforms the surface and leaves compressive residual stress, reducing the effective tensile range at likely initiation sites. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

40. D — Corrosion requires simultaneous anodic and cathodic reactions. Iron dissolves at anodic sites while dissolved oxygen is commonly reduced at cathodic sites; electron and ion paths complete the cell. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

41. B — A large cathode can support substantial reduction current concentrated on a small anodic area, creating high anodic current density and rapid penetration. Reversing the area ratio reduces severity. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

42. C — Chromium promotes a thin, continuous, self-repairing oxide that sharply reduces dissolution. Damage can repassivate when the environment supplies sufficient oxidizing potential and is not overly aggressive. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The

competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

43. D — SCC occurs only when material susceptibility, tensile stress, and an appropriate environment overlap. Removing any leg of this combination can prevent cracking, even if the other two remain. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

44. A — Absorbed hydrogen facilitates localized damage and delayed cracking, especially in high-strength steels under tensile stress. The principal concern is lost ductility and fracture resistance, not a major change in modulus. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses.

45. C — Above T_g , amorphous chain segments gain mobility, causing a marked decrease in modulus and increased damping or rubbery response. Melting is a separate transition for crystalline regions. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

46. D — Creep is time-dependent strain under sustained load and becomes important at sufficiently high temperature relative to melting temperature. Duration, stress, and microstructure govern the rate. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

47. B — Secondary creep shows an approximately constant minimum rate because work hardening is balanced by recovery. Primary creep decelerates, whereas tertiary creep accelerates as damage and section loss accumulate. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

48. A — An S-N curve relates alternating stress amplitude to fatigue life. It is useful for stress-life design, especially high-cycle fatigue, whereas other plots characterize creep, impact transition, or indentation. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. That distinction is important when applying the concept to engineering decisions.

49. A — Goodman and Gerber relations account for the damaging interaction of mean tensile stress with alternating stress. They convert the loading state into a fatigue design criterion. Engineering assessment must identify the controlling damage mechanism before selecting mitigation. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

50. C — Near the end of solidification, coherent dendrites may lack ductility while contraction is restrained by mold geometry or section changes. Tensile strain then opens an irregular crack. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

51. B — Hydrogen solubility drops sharply during aluminum solidification, so excess dissolved gas forms pores. Degassing and dry, clean handling reduce the initial hydrogen content and entrainment. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

52. D — Preheat slows cooling, reduces hard martensitic microstructures, promotes hydrogen diffusion, and lowers thermal gradients. These effects reduce delayed hydrogen cracking risk in susceptible steels. Process

variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

53. D — In the sensitization range, chromium carbides precipitate at boundaries and draw chromium from adjacent regions. The depleted zones may fall below the concentration needed for stable passivity. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

54. B — Brazing heats the assembly above the filler liquidus but below the base-metal solidus. Molten filler flows through the joint by capillary action and solidifies to bond the parts. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses.

55. A — Austenitized steel is quenched to a temperature above martensite start and held until austenite transforms isothermally to bainite. This can provide good strength and toughness with reduced distortion. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses.

56. C — The part is quenched to just above martensite start and held briefly for temperature equalization, then cooled through transformation. More uniform transformation reduces thermal and transformation stresses. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

57. A — Agitated brine disrupts the vapor blanket and extracts heat rapidly, giving high quench severity. Oil is milder, while air and vacuum cooling are much slower. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

58. C — Solution treatment and quenching create a supersaturated solid solution; aging forms fine precipitates that resist dislocation motion. Overaging coarsens them and usually reduces strength. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

59. D — Carbon diffuses into the surface at austenitizing temperature. Subsequent quenching can form a hard martensitic case while the low-carbon interior retains toughness and impact resistance. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

60. B — Nitrogen diffuses into suitable alloy steel and forms fine nitrides at temperatures below austenitizing. Because no martensitic quench is normally required, dimensional change and distortion are comparatively low. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses.

61. A — Atomic transport forms and enlarges interparticle necks because reducing free surface area lowers system energy. Densification may occur through several diffusion and flow mechanisms depending on conditions. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

62. D — HIP combines elevated temperature with isostatic gas pressure, promoting diffusion and plastic flow that close internal pores. Uniform pressure limits directional distortion compared with uniaxial pressing. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices

describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

63. B — Insufficient energy leaves unmelted boundaries and lack-of-fusion pores; excessive energy can create unstable deep keyholes, evaporation, and porosity. Scan speed, power, hatch spacing, and layer thickness interact. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

64. C — Strength along extruded roads can exceed strength across layer interfaces, where bonding depends on temperature, wetting, diffusion, and void content. Build orientation therefore affects mechanical performance. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

65. A — Accelerated droplets or particles flatten into splats on impact and mechanically anchor to a clean, rough surface. Some systems also develop chemical or metallurgical bonding, but preparation remains essential. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses.

66. B — Faraday's law relates deposited mass to charge passed, so current and time are central. Current efficiency and the species electrochemical equivalent convert charge to actual deposited material. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

67. D — Zinc is more active than iron and preferentially dissolves when electrically connected in an electrolyte, providing sacrificial protection. Barrier action also contributes while the coating remains intact. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

68. C — Cleaning, abrasion, plasma treatment, or primers remove weak contamination and raise surface energy or chemical reactivity. Better wetting and bonding allow load transfer across the interface. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

69. B — DSC records heat flow into or from a specimen relative to a reference, revealing glass transition, melting, crystallization, curing, and other thermal events. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

70. A — Dynamic and subsequent recrystallization restore ductility during hot working, enabling large reductions with lower flow stress. Surface finish and dimensional control are generally poorer than in cold rolling. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses.

71. C — Plastic deformation multiplies and entangles dislocations, increasing resistance to further slip. Strength and hardness rise while ductility falls; recovery and recrystallization can later reverse these effects. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

72. D — Recovery permits dislocation rearrangement, annihilation, and polygonization with modest property changes and stress relief. Recrystallization later creates new, low-dislocation-density grains. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe

different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

73. C — Recrystallization nucleates and grows new grains with low dislocation density until the deformed matrix is consumed. Subsequent grain growth is a separate stage driven by boundary-energy reduction. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. That distinction is important when applying the concept to engineering decisions.

74. A — A properly located riser remains liquid longer than the casting region it feeds, providing metal as solidification shrinkage occurs. Directional solidification toward the riser helps prevent shrinkage cavities. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses.

75. D — Disposable wax patterns and ceramic shells reproduce fine detail and undercuts with good finish and dimensional accuracy. Tooling and processing cost make it less suitable for every application. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses.

76. B — Holding pressure packs additional polymer into the cavity as it cools and contracts. Inadequate packing allows local shrinkage, producing sinks or voids in thick sections. Process variables govern heat flow, deformation, mass transport, defects, and final microstructure. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

77. A — TEM forms images and diffraction patterns from electrons transmitted through an electron-transparent foil. Excess thickness causes strong scattering and absorption that obscure interpretable signals. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

78. D — EBSD patterns collected in an SEM are indexed to determine local crystal orientation. Raster mapping reveals grains, texture, phase orientation, and boundary misorientation. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

79. C — A spark or arc excites atoms, and their emitted spectral lines identify elements. Calibrated line intensities support quantitative bulk alloy analysis over an appropriate sampling region. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

80. B — TGA continuously measures mass change, revealing oxidation, decomposition, volatilization, moisture loss, or residue formation. Coupling with evolved-gas analysis can help identify the species responsible. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

81. B — DMA applies oscillatory deformation and separates elastic storage from viscous loss response. Temperature or frequency sweeps reveal glass transition, secondary relaxations, and viscoelastic behavior. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

82. D — Rockwell testing measures the change in penetration depth between load steps. Brinell and Vickers methods use optical indentation dimensions, while rebound methods use different principles. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

83. C — A diamond pyramid produces a square impression whose diagonals are measured. Load divided by the calculated sloping surface area gives the Vickers hardness value. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

84. A — A line parallel to the elastic slope, offset by 0.002 strain, intersects the stress-strain curve at the conventional yield strength. It defines a reproducible onset of plasticity. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

85. D — Engineering stress divides load by original area, whereas true stress uses instantaneous area. During necking, local area shrinks substantially, so engineering stress understates the actual local stress. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

86. B — Electrical resistance changes as the bonded grid stretches or contracts. Through its gauge factor, the measured resistance change gives normal strain along the grid direction. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

87. C — Three measurements at known angles allow transformation of the in-plane strain state, giving principal strains and their directions. A single gauge cannot resolve an unknown biaxial state. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

88. A — A fatigue precrack creates a naturally sharp crack and realistic crack-tip field. A machined notch alone is too blunt and can overestimate resistance to crack extension. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

89. D — In the intermediate stable-growth regime, da/dN is modeled as a material constant times a power of ΔK . Threshold and rapid-fracture regimes require other considerations. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

90. C — Mixed-potential analysis balances anodic and cathodic currents at the corrosion potential. Appropriate polarization data and extrapolation can estimate corrosion current density and penetration rate. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

91. A — Salt spray provides controlled comparative screening of coatings and processes. Field performance depends on service chemistry, wet-dry cycling, geometry, damage, and other factors not reproduced exactly. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

92. B — Etchants react at different rates with phases, orientations, and boundaries, producing topographic or optical contrast. Proper polishing must precede etching to avoid confusing preparation damage with structure. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

93. A — Stereological principles equate expected area fraction on representative sections with volume fraction. Adequate sampling and unbiased field selection are essential for a defensible estimate. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

94. C — The number of boundary intercepts over a known total line length gives a mean intercept length related to grain size. Randomized lines and sufficient counts reduce bias. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. The stated conditions therefore support only the keyed response.

95. B — Buoyancy equals the weight of displaced liquid. Comparing dry and immersed apparent mass yields specimen volume, which combined with dry mass gives bulk density. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

96. D — Separate current-carrying and voltage-sensing leads prevent most contact and lead voltage drops from entering the measured specimen voltage. This improves low-resistance measurements. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

97. B — Constructive interference occurs when path differences equal integer wavelengths, expressed by Bragg's law. Measured peak positions reveal lattice spacings that can be matched to crystalline phases. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

98. C — Finite crystallite size and distributions of lattice strain broaden diffraction peaks. Instrumental broadening must be separated before quantitative size or strain estimates are made. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

99. D — A focused electron beam scans the surface, and emitted signals form high-resolution images with substantial depth of field. Compositional contrast and microanalysis can also be obtained. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.

100. A — Electron-beam ionization produces element-specific X-ray energies. Peak identities indicate elements, while intensities support approximate quantification subject to interaction-volume and correction effects. Interpretation must respect specimen preparation, sampling volume, calibration, and method limitations. The competing choices describe different mechanisms, tests, or material responses. That distinction is important when applying the concept to engineering decisions.