

PRACTICE EXAM 21: 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. For a component qualification review, select the best response: Increasing temperature generally accelerates substitutional diffusion because it does what?

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

2. A metallurgical engineer examining the evidence asks: During homogeneous nucleation, the critical nucleus forms when which energy balance is reached?

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

3. During materials-process troubleshooting, determine the correct answer: In a binary eutectic reaction on cooling, one liquid transforms into what?

- A. One solid solution only
- B. A liquid plus one solid

- C. Two solid phases simultaneously
- D. A gas and one solid

4. For the stated service condition, which conclusion is technically sound? What does the lever rule determine in a two-phase region of a binary phase diagram?

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

5. Apply the governing structure-property principle: A hypoeutectoid steel slowly cooled below the eutectoid temperature contains which constituents?

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

6. For a component qualification review, select the best response: Rapidly quenching austenitic steel below the martensite-start temperature produces martensite primarily by what mechanism?

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

7. A metallurgical engineer examining the evidence asks: 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

8. During materials-process troubleshooting, determine the correct answer: A transgranular cleavage fracture surface is most likely to show which microscopic feature?

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

9. For the stated service condition, which conclusion is technically sound? Which bond type chiefly explains the high electrical conductivity and nondirectional deformation behavior of most metals?

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

10. Apply the governing structure-property principle: Cross-linking a thermosetting polymer generally has which effect?

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

11. For a component qualification review, select the best response: A low-angle grain boundary can be modeled most directly as what?

- A. A layer of amorphous liquid
- B. An ordered array of dislocations
- C. A single coherent precipitate
- D. A vacancy-free perfect crystal

12. A metallurgical engineer examining the evidence asks: Which crystal structure has the highest atomic packing factor among the choices?

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

13. During materials-process troubleshooting, determine the correct answer: 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. Completely different valence states
- D. Atomic radii differing by less than about 15 percent

14. For the stated service condition, which conclusion is technically sound? 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

15. Apply the governing structure-property principle: 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. $a/3\langle 112 \rangle$

16. For a component qualification review, select the best response: Fick's first law describes diffusion under which condition?

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

17. A metallurgical engineer examining the evidence asks: Plane-strain fracture toughness is generally lower than plane-stress toughness because plane strain has what?

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

18. During materials-process troubleshooting, determine the correct answer: 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

19. For the stated service condition, which conclusion is technically sound? Abrasive wear occurs primarily when what happens?

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

20. Apply the governing structure-property principle: Adhesive wear and galling are promoted most strongly by which condition?

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

21. For a component qualification review, select the best response: Elastohydrodynamic lubrication is associated most closely with what contacts?

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

22. A metallurgical engineer examining the evidence asks: A control chart point beyond a statistically established control limit most directly suggests what?

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

23. During materials-process troubleshooting, determine the correct answer: A high process capability index requires what relationship?

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

24. For the stated service condition, which conclusion is technically sound? Liquid penetrant testing is best suited to detecting which discontinuities?

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

25. Apply the governing structure-property principle: Magnetic-particle inspection can detect flaws in which materials?

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

26. For a component qualification review, select the best response: Ultrasonic pulse-echo inspection locates an internal reflector primarily from what measurement?

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

27. A metallurgical engineer examining the evidence 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. Residual stress with no density change
- D. Volumetric flaws or planar flaws aligned with the beam

28. During materials-process troubleshooting, determine the correct answer: In failure analysis, preserving fracture surfaces before cleaning is essential because cleaning may do what?

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

29. For the stated service condition, which conclusion is technically sound? A fishbone diagram in a failure investigation is used primarily to do what?

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

30. Apply the governing structure-property principle: Fitness-for-service assessment differs from simple code acceptance because it does what?

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

31. For a component qualification review, select the best response: For material selection using an Ashby chart, a performance index is used to do what?

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

32. A metallurgical engineer examining the evidence asks: Recycling aluminum generally saves substantial energy compared with primary production because it avoids what?

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

33. During materials-process troubleshooting, determine the correct answer: 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. The equilibrium vacancy concentration
- D. Which processes and environmental burdens are included

34. For the stated service condition, which conclusion is technically sound? Thermal shock resistance of a brittle ceramic is generally improved by which property combination?

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

35. Apply the governing structure-property principle: 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

36. For a component qualification review, select the best response: 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

37. A metallurgical engineer examining the evidence asks: Shot peening improves fatigue resistance mainly by introducing what?

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

38. During materials-process troubleshooting, determine the correct answer: 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

39. For the stated service condition, which conclusion is technically sound? For galvanically coupled metals in an electrolyte, which configuration most severely attacks the anodic metal?

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

40. Apply the governing structure-property principle: 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

41. For a component qualification review, select the best response: Stress-corrosion cracking requires which combination?

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

42. A metallurgical engineer examining the evidence asks: Hydrogen embrittlement most directly reduces which property of a high-strength steel?

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

43. During materials-process troubleshooting, determine the correct answer: A polymer exposed above its glass-transition temperature generally exhibits what change?

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

44. For the stated service condition, which conclusion is technically sound? 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

45. Apply the governing structure-property principle: During steady-state secondary creep, the strain rate is approximately what?

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

46. For a component qualification review, select the best response: 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

47. A metallurgical engineer examining the evidence asks: A component subjected to a mean stress plus alternating stress is commonly assessed using which relation?

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

48. During materials-process troubleshooting, determine the correct answer: Fatigue beach marks on a fracture surface indicate what?

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

49. For the stated service condition, which conclusion is technically sound? For linear-elastic fracture mechanics, unstable crack growth begins when what occurs?

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

50. Apply the governing structure-property principle: Hot isostatic pressing improves a powder or casting by applying what?

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

51. For a component qualification review, select the best response: 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. Ordinary solidification whenever a stable melt pool cools below liquidus
- C. All residual stress regardless of scan pattern or preheating strategy
- D. Lack of fusion at low input and keyhole porosity at excessive input

52. A metallurgical engineer examining the evidence 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

53. During materials-process troubleshooting, determine the correct answer: A thermal-spray coating adheres to a roughened substrate mainly through what?

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

54. For the stated service condition, which conclusion is technically sound? Electroplating thickness on a cathodic workpiece is governed most directly by what variables?

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

55. Apply the governing structure-property principle: 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

56. For a component qualification review, select the best response: 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

57. A metallurgical engineer examining the evidence 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

58. During materials-process troubleshooting, determine the correct answer: Hot rolling is performed above the recrystallization temperature mainly to obtain what benefit?

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

59. For the stated service condition, which conclusion is technically sound? 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

60. Apply the governing structure-property principle: During recovery of a cold-worked metal, which change occurs before recrystallization?

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

61. For a component qualification review, select the best response: 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

62. A metallurgical engineer examining the evidence asks: In sand casting, a riser is designed primarily to do what?

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

63. During materials-process troubleshooting, determine the correct answer: Investment casting is selected when a component requires what?

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

64. For the stated service condition, which conclusion is technically sound? In injection molding, insufficient holding pressure most directly promotes which defect?

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

65. Apply the governing structure-property 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. Restricted contraction while the alloy is weak near the end of solidification
- C. Uniform elastic contraction of the casting without any external restraint
- D. Complete absence of a freezing range during alloy solidification

66. For a component qualification review, select the best response: Gas porosity in an aluminum casting can be reduced by what action?

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

67. A metallurgical engineer examining the evidence asks: In arc welding steel, preheating a thick hardenable joint mainly reduces what risk?

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

68. During materials-process troubleshooting, determine the correct 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. Chromium carbide precipitation depletes chromium near grain boundaries
- D. Carbon dissolves all grain boundaries

69. For the stated service condition, which conclusion is technically sound? Brazing differs from fusion welding because brazing does what?

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

70. Apply the governing structure-property principle: Austempering steel is designed to produce predominantly which microstructure?

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

71. For a component qualification review, select the best 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. Holding above the austenitizing temperature
- D. Equalizing temperature before martensitic transformation proceeds through the section

72. A metallurgical engineer examining the evidence asks: Quench severity is highest for which medium under typical conditions?

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

73. During materials-process troubleshooting, determine the correct answer: Precipitation hardening achieves peak strength through what feature?

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

74. For the stated service condition, which conclusion is technically sound? Carburizing a low-carbon steel component is used primarily to create what?

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

75. Apply the governing structure-property principle: Nitriding can produce a hard case with relatively low distortion because it commonly does what?

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

76. For a component qualification review, select the best response: During powder sintering, neck growth between particles is driven primarily by what?

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

77. A metallurgical engineer examining the evidence asks: Scanning electron microscopy is especially useful for examining what?

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

78. During materials-process troubleshooting, determine the correct answer: In SEM-based energy-dispersive spectroscopy, characteristic X-rays reveal what?

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

79. For the stated service condition, which conclusion is technically sound? Transmission electron microscopy requires a very thin specimen primarily so that what can occur?

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

80. Apply the governing structure-property principle: Electron backscatter diffraction is used chiefly to map what?

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

81. For a component qualification review, select the best response: Optical emission spectroscopy of a metal determines composition by analyzing what?

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

82. A metallurgical engineer examining the evidence asks: Thermogravimetric analysis records which quantity as temperature or time changes?

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

83. During materials-process troubleshooting, determine the correct answer: Dynamic mechanical analysis of a polymer measures what response?

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

84. For the stated service condition, which conclusion is technically sound? A Rockwell hardness test determines hardness from what?

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

85. Apply the governing structure-property principle: The Vickers hardness number is calculated using what?

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

86. For a component qualification review, select the best response: In a tensile test, the 0.2-percent offset method estimates what?

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

87. A metallurgical engineer examining the evidence asks: 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

88. During materials-process troubleshooting, determine the correct answer: A strain gauge aligned with the loading direction measures which quantity directly?

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

89. For the stated service condition, which conclusion is technically sound? A three-element strain-gauge rosette is used when what is unknown?

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

90. Apply the governing structure-property principle: Fracture toughness testing requires a fatigue precrack primarily to provide what?

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

91. For a component qualification review, select the best response: 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

92. A metallurgical engineer examining the evidence asks: A corrosion polarization curve can provide an estimate of corrosion current density from what?

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

93. During materials-process troubleshooting, determine the correct answer: 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

94. For the stated service condition, which conclusion is technically sound? 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

95. Apply the governing structure-property principle: For quantitative metallography, the area fraction of a phase on a representative random plane estimates what?

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

96. For a component qualification review, select the best response: The linear-intercept method estimates grain size by counting what?

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

97. A metallurgical engineer examining the evidence asks: Archimedes' method determines bulk density from what measurements?

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

98. During materials-process troubleshooting, determine the correct answer: A four-point electrical resistivity measurement reduces error from what?

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

99. For the stated service condition, which conclusion is technically sound? X-ray diffraction identifies crystalline phases mainly through which relation?

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

100. Apply the governing structure-property principle: 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

Practice Exam 21: Answer Key and Explanations

1. D — 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.

2. B — 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.

3. C — 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.

4. A — 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.

5. D — 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.

6. B — 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.

7. 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.

8. C — 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.

9. A — 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.

10. D — 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.

11. B — 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.

12. A — 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.

13. D — 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.

14. 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.

15. 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.

16. C — 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.

17. C — 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.

18. 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.

19. A — 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.

20. B — 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.

21. A — 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.

22. B — 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.

23. C — 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.

24. D — 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.

25. C — 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.

26. A — 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.

27. D — 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.

28. B — 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.

29. D — 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.

30. B — 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.

31. A — 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.

32. C — 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.

33. D — 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.

34. A — 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.

35. 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.

36. 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.

37. B — 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.

38. 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.

39. A — 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.

40. 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.

41. B — 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.

42. D — 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.

43. A — 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.

44. 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.

45. C — 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.

46. 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.

47. C — 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.

48. B — 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.

49. A — 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.

50. B — 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.

51. D — 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.

52. 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.

53. B — 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.

54. A — 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.

55. 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.

56. 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.

57. 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.

58. D — 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.

59. 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.

60. A — 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.

61. 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.

- 62. B** — 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.
- 63. A** — 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.
- 64. D** — 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.
- 65. B** — 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.
- 66. D** — 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.
- 67. A** — 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.
- 68. C** — 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.
- 69. A** — 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.
- 70. C** — 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.
- 71. D** — 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.

72. B — 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.

73. B — 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.

74. A — 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.

75. C — 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.

76. D — 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.

77. B — 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.

78. C — 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.

79. D — 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.

80. A — 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.

81. B — 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.

82. D — 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.

83. A — 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.

84. C — 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.

85. A — 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.

86. B — 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.

87. 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.

88. C — 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.

89. A — 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.

90. C — 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.

91. 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.

92. B — 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.

93. 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.

94. 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.

95. C — 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.

96. D — 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.

97. D — 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.

98. B — 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.

99. A — 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.

100. 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.