

PRACTICE EXAM 12: PE METALLURGICAL AND MATERIALS SIMULATION (100 QUESTIONS)

This standalone 100-question simulation uses the approved NCEES-scaled allocation: Structure 16, Performance 33, Processing 27, and Characterization and Properties 24. The official PE Metallurgical and Materials examination contains 85 questions and provides 8.5 hours of testing time. Use applicable SI or U.S. Customary conventions and select the single best response. NCEES does not publish a numerical passing score.

1. A materials engineer reviewing a high-consequence application asks: Rapidly quenching austenitic steel below the martensite-start temperature produces martensite primarily by what mechanism?

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

2. During an independent qualification review, choose the best response: 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

3. A plant metallurgist examining process variation must determine: What does the lever rule determine in a two-phase region of a binary phase diagram?

- A. The nucleation rate
- B. The relative amounts of the two equilibrium phases

- C. The diffusion coefficient
- D. The crystal structure of each phase

4. Applying the relevant thermodynamic or kinetic principle, a low-angle grain boundary can be modeled most directly as what?

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

5. A service-performance investigation raises this question: During homogeneous nucleation, the critical nucleus forms when which energy balance is reached?

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

6. Given the available microstructural and operating evidence, 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

7. A manufacturing-development team must resolve: Fick's first law describes diffusion under which condition?

- A. Grain growth controlled by curvature

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

8. For the stated material system and boundary conditions, tempering quenched martensitic steel primarily accomplishes which result?

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

9. A laboratory engineer interpreting the measured response asks: An edge dislocation is characterized by which feature?

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

10. To support a technically sound decision, select the correct 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

11. A materials engineer reviewing a high-consequence application asks: Which crystal structure has the highest atomic packing factor among the choices?

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

12. During an independent qualification review, choose the best response: In a binary eutectic reaction on cooling, one liquid transforms into what?

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

13. A plant metallurgist examining process variation must determine: Cross-linking a thermosetting polymer generally has which effect?

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

14. Applying the relevant thermodynamic or kinetic principle, 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

15. A service-performance investigation raises this question: A transgranular cleavage fracture surface is most likely to show which microscopic feature?

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

16. Given the available microstructural and operating evidence, in a BCC metal, the Burgers vector for a perfect dislocation is commonly of which type?

- A. $a/3\langle 112 \rangle$
- B. $a/2\langle 111 \rangle$
- C. $a/2\langle 110 \rangle$
- D. $a\langle 100 \rangle$

17. A manufacturing-development team must resolve: For linear-elastic fracture mechanics, unstable crack growth begins when what occurs?

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

18. For the stated material system and boundary conditions, 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

19. A laboratory engineer interpreting the measured response asks: A fishbone diagram in a failure investigation is used primarily to do what?

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

20. To support a technically sound decision, select the correct answer: Abrasive wear occurs primarily when what happens?

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

21. A materials engineer reviewing a high-consequence application asks: Hydrogen embrittlement most directly reduces which property of a high-strength steel?

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

22. During an independent qualification review, choose the best response: 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

23. A plant metallurgist examining process variation must determine: A control chart point beyond a statistically established control limit most directly suggests what?

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

24. Applying the relevant thermodynamic or kinetic principle, during steady-state secondary creep, the strain rate is approximately what?

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

25. A service-performance investigation raises this question: Oxidation resistance of an alloy at high temperature is best when the scale is what?

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

26. Given the available microstructural and operating evidence, magnetic-particle inspection can detect flaws in which materials?

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

27. A manufacturing-development team must resolve: Fatigue beach marks on a fracture surface indicate what?

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

28. For the stated material system and boundary conditions, uniform corrosion of carbon steel in an aerated neutral electrolyte is an example of what process?

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

29. A laboratory engineer interpreting the measured response asks: In failure analysis, preserving fracture surfaces before cleaning is essential because cleaning may do what?

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

30. To support a technically sound decision, select the correct answer: Charpy impact testing of ferritic steel is especially useful for identifying what?

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

31. A materials engineer reviewing a high-consequence application asks: Stress-corrosion cracking requires which combination?

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

32. During an independent qualification review, choose the best response: For material selection using an Ashby chart, a performance index is used to do what?

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

33. A plant metallurgist examining process variation must determine: Elastohydrodynamic lubrication is associated most closely with what contacts?

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

34. Applying the relevant thermodynamic or kinetic principle, 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. Sustained stress at elevated homologous temperature
- D. Elastic unloading without time dependence

35. A service-performance investigation raises this question: Thermal shock resistance of a brittle ceramic is generally improved by which property combination?

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

36. Given the available microstructural and operating evidence, liquid penetrant testing is best suited to detecting which discontinuities?

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

37. A manufacturing-development team must resolve: A component subjected to a mean stress plus alternating stress is commonly assessed using which relation?

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

38. For the stated material system and boundary conditions, shot peening improves fatigue resistance mainly by introducing what?

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

39. A laboratory engineer interpreting the measured response asks: Radiographic testing is generally most sensitive to which flaw orientation?

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

40. To support a technically sound decision, select the correct answer: Plane-strain fracture toughness is generally lower than plane-stress toughness because plane strain has what?

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

41. A materials engineer reviewing a high-consequence application asks: Passivity in stainless steel is primarily provided by which surface feature?

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

42. During an independent qualification review, choose the best response: Fitness-for-service assessment differs from simple code acceptance because it does what?

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

43. A plant metallurgist examining process variation must determine: Adhesive wear and galling are promoted most strongly by which condition?

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

44. Applying the relevant thermodynamic or kinetic principle, a polymer exposed above its glass-transition temperature generally exhibits what change?

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

45. A service-performance investigation raises this question: A life-cycle assessment should define system boundaries before comparing materials because boundaries determine what?

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

46. Given the available microstructural and operating evidence, 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

47. A manufacturing-development team must resolve: Which S-N curve feature defines fatigue endurance behavior?

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

48. For the stated material system and boundary conditions, a Pilling-Bedworth ratio near unity often favors protective oxidation because the oxide volume is what?

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

49. A laboratory engineer interpreting the measured response asks: Ultrasonic pulse-echo inspection locates an internal reflector primarily from what measurement?

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

50. To support a technically sound decision, select the correct answer: Austempering steel is designed to produce predominantly which microstructure?

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

51. A materials engineer reviewing a high-consequence application asks: Gas porosity in an aluminum casting can be reduced by what action?

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

52. During an independent qualification review, choose the best response: In sand casting, a riser is designed primarily to do what?

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

53. A plant metallurgist examining process variation must determine: Hot rolling is performed above the recrystallization temperature mainly to obtain what benefit?

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

54. Applying the relevant thermodynamic or kinetic principle, electroplating thickness on a cathodic workpiece is governed most directly by what variables?

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

55. A service-performance investigation raises this question: Hot isostatic pressing improves a powder or casting by applying what?

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

56. Given the available microstructural and operating evidence, precipitation hardening achieves peak strength through what feature?

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

57. A manufacturing-development team must resolve: Brazing differs from fusion welding because brazing does what?

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

58. For the stated material system and boundary conditions, 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. Complete absence of a freezing range during alloy solidification
- D. Restricted contraction while the alloy is weak near the end of solidification

59. A laboratory engineer interpreting the measured response asks: Primary recrystallization is complete when what has occurred?

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

60. To support a technically sound decision, select the correct answer: Differential scanning calorimetry measures what during a programmed temperature change?

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

61. A materials engineer reviewing a high-consequence application asks: A thermal-spray coating adheres to a roughened substrate mainly through what?

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

62. During an independent qualification review, choose the best 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

63. A plant metallurgist examining process variation must determine: Quench severity is highest for which medium under typical conditions?

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

64. Applying the relevant thermodynamic or kinetic principle, a sensitized austenitic stainless steel is vulnerable to intergranular corrosion because of what?

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

65. A service-performance investigation raises this question: In injection molding, insufficient holding pressure most directly promotes which defect?

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

66. Given the available microstructural and operating evidence, 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

67. A manufacturing-development team must resolve: In adhesive bonding of polymers or composites, surface preparation primarily improves what?

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

68. For the stated material system and boundary conditions, fused-filament fabrication commonly produces anisotropic polymer parts because of what?

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

69. A laboratory engineer interpreting the measured response asks: Nitriding can produce a hard case with relatively low distortion because it commonly does what?

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

70. To support a technically sound decision, select the correct answer: Martempering reduces quench distortion by doing what?

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

71. A materials engineer reviewing a high-consequence application asks: In arc welding steel, preheating a thick hardenable joint mainly reduces what risk?

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

72. During an independent qualification review, choose the best response: Investment casting is selected when a component requires what?

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

73. A plant metallurgist examining process variation must determine: Cold working a ductile metal generally causes which property change?

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

74. Applying the relevant thermodynamic or kinetic principle, galvanizing protects steel even at small coating scratches because zinc does what?

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

75. A service-performance investigation raises this question: Selective laser melting of metal powder requires control of energy density chiefly to avoid what tradeoff?

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

76. Given the available microstructural and operating evidence, carburizing a low-carbon steel component is used primarily to create what?

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

77. A manufacturing-development team must resolve: A strain gauge aligned with the loading direction measures which quantity directly?

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

78. For the stated material system and boundary conditions, engineering stress differs from true stress after necking because engineering stress uses what area?

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

79. A laboratory engineer interpreting the measured response asks: In a tensile test, the 0.2-percent offset method estimates what?

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

80. To support a technically sound decision, select the correct answer: The Vickers hardness number is calculated using what?

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

81. A materials engineer reviewing a high-consequence application asks: A Rockwell hardness test determines hardness from what?

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

82. During an independent qualification review, choose the best response: Dynamic mechanical analysis of a polymer measures what response?

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

83. A plant metallurgist examining process variation must determine: Thermogravimetric analysis records which quantity as temperature or time changes?

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

84. Applying the relevant thermodynamic or kinetic principle, optical emission spectroscopy of a metal determines composition by analyzing what?

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

85. A service-performance investigation raises this question: Electron backscatter diffraction is used chiefly to map what?

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

86. Given the available microstructural and operating evidence, transmission electron microscopy requires a very thin specimen primarily so that what can occur?

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

87. A manufacturing-development team must resolve: In SEM-based energy-dispersive spectroscopy, characteristic X-rays reveal what?

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

88. For the stated material system and boundary conditions, scanning electron microscopy is especially useful for examining what?

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

89. A laboratory engineer interpreting the measured response asks: Peak broadening in an X-ray diffraction pattern can indicate what?

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

90. To support a technically sound decision, select the correct answer: 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

91. A materials engineer reviewing a high-consequence application asks: A four-point electrical resistivity measurement reduces error from what?

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

92. During an independent qualification review, choose the best response: Archimedes' method determines bulk density from what measurements?

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

93. A plant metallurgist examining process variation must determine: The linear-intercept method estimates grain size by counting what?

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

94. Applying the relevant thermodynamic or kinetic principle, 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

95. A service-performance investigation raises this question: Metallographic etching reveals microstructure mainly by what mechanism?

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

96. Given the available microstructural and operating evidence, salt-spray testing is best interpreted as what kind of test?

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

97. A manufacturing-development team must resolve: A corrosion polarization curve can provide an estimate of corrosion current density from what?

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

98. For the stated material system and boundary conditions, in fatigue crack-growth testing, the Paris relation connects crack-growth rate with what?

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

99. A laboratory engineer interpreting the measured response asks: Fracture toughness testing requires a fatigue precrack primarily to provide what?

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

100. To support a technically sound decision, select the correct answer: A three-element strain-gauge rosette is used when what is unknown?

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

Practice Exam 12: Answer Key and Explanations

1. D — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.

2. C — For the stated evidence, similar atomic size limits lattice strain. Similar structure, electronegativity, and valence also favor extensive solubility; the listed alternatives generally reduce it. Atomic configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem. Therefore, the keyed answer alone satisfies the complete technical scenario.

3. B — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.

4. A — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.

5. B — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.

- 6. A** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 7. C** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 8. D** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 9. D** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 10. B** — For the stated evidence, below the eutectoid carbon content, ferrite forms before the eutectoid reaction; remaining austenite transforms to pearlite. Proeutectoid cementite occurs in hypereutectoid steel. The distractors refer to other phenomena or conflict with a condition in the stem. Therefore, the keyed answer alone satisfies the complete technical scenario.
- 11. C** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 12. A** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 13. D** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 14. A** — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.
- 15. C** — For the stated evidence, cleavage propagates through grains along crystallographic planes, producing facets and converging river patterns. Dimples indicate ductile rupture, while boundary facets indicate intergranular fracture. Atomic configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.

16. B — For the stated evidence, 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 configuration and transformation energetics provide the governing explanation. The distractors refer to other phenomena or conflict with a condition in the stem.

17. A — For the stated evidence, mode I instability is expected when KI equals or exceeds the appropriate toughness under valid constraint conditions. Crack size, geometry, and applied stress jointly determine KI. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

18. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

19. D — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

20. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

21. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. Therefore, the keyed answer alone satisfies the complete technical scenario.

22. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

23. D — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

24. A — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

25. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

26. D — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

27. A — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. Therefore, the keyed answer alone satisfies the complete technical scenario.

28. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

29. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

30. A — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

31. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

32. D — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

33. D — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

34. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

35. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

36. A — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

37. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

38. D — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

39. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

40. A — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

41. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

42. A — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

43. D — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

44. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

45. D — For the stated evidence, system boundaries decide whether extraction, manufacturing, transport, use, maintenance, recycling, and disposal are counted. Inconsistent boundaries can reverse an apparent environmental comparison. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

46. B — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

47. C — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

48. A — For the stated evidence, 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. The distractors refer to other phenomena or conflict with a condition in the stem.

49. A — For the stated evidence, 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. Service conditions and the active degradation mode control the engineering response. The distractors refer to other phenomena or conflict with a condition in the stem.

50. D — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

51. C — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

52. B — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

53. D — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

54. C — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

55. A — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

- 56. B** — For the stated evidence, solution treatment and quenching create a supersaturated solid solution; aging forms fine precipitates that resist dislocation motion. Overaging coarsens them and usually reduces strength. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 57. C** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 58. D** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 59. A** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 60. B** — For the stated evidence, DSC records heat flow into or from a specimen relative to a reference, revealing glass transition, melting, crystallization, curing, and other thermal events. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 61. D** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 62. A** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 63. C** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 64. B** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.
- 65. A** — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

66. D — For the stated evidence, recovery permits dislocation rearrangement, annihilation, and polygonization with modest property changes and stress relief. Recrystallization later creates new, low-dislocation-density grains. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem. Therefore, the keyed answer alone satisfies the complete technical scenario.

67. B — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

68. C — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

69. D — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

70. B — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

71. A — For the stated evidence, preheat slows cooling, reduces hard martensitic microstructures, promotes hydrogen diffusion, and lowers thermal gradients. These effects reduce delayed hydrogen cracking risk in susceptible steels. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

72. C — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

73. B — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

74. A — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

75. D — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

76. C — For the stated evidence, 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. The process route governs microstructure, defect formation, and resulting properties. The distractors refer to other phenomena or conflict with a condition in the stem.

77. B — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

78. C — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

79. D — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

80. A — For the stated evidence, a diamond pyramid produces a square impression whose diagonals are measured. Load divided by the calculated sloping surface area gives the Vickers hardness value. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

81. A — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

82. D — For the stated evidence, DMA applies oscillatory deformation and separates elastic storage from viscous loss response. Temperature or frequency sweeps reveal glass transition, secondary relaxations, and viscoelastic behavior. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

83. B — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

84. C — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

85. D — For the stated evidence, EBSD patterns collected in an SEM are indexed to determine local crystal orientation. Raster mapping reveals grains, texture, phase orientation, and boundary misorientation. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

- 86. B** — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 87. C** — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem. That relationship supports the final engineering conclusion.
- 88. A** — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 89. C** — For the stated evidence, finite crystallite size and distributions of lattice strain broaden diffraction peaks. Instrumental broadening must be separated before quantitative size or strain estimates are made. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 90. A** — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 91. B** — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 92. D** — For the stated evidence, buoyancy equals the weight of displaced liquid. Comparing dry and immersed apparent mass yields specimen volume, which combined with dry mass gives bulk density. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 93. D** — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 94. A** — For the stated evidence, stereological principles equate expected area fraction on representative sections with volume fraction. Adequate sampling and unbiased field selection are essential for a defensible estimate. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.
- 95. B** — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

96. C — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

97. D — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

98. A — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

99. C — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.

100. B — For the stated evidence, 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. Signal generation, specimen condition, and resolution limit the supported conclusion. The distractors refer to other phenomena or conflict with a condition in the stem.