

PRACTICE EXAM 19: 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. In an alloy-development review, select the technically sound response: Applying the relevant thermodynamic or kinetic principle, a low-angle grain boundary can be modeled most directly as what?

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

2. A materials engineer investigating field behavior asks: During homogeneous nucleation, the critical nucleus forms when which energy balance is reached?

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

3. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, Given the available microstructural and operating evidence, which bond type chiefly explains the high electrical conductivity and nondirectional deformation behavior of most metals?

- A. Ionic bonding
- B. Metallic bonding

- C. Covalent network bonding
- D. Hydrogen bonding

4. During interpretation of test results, which conclusion is correct? During process qualification, which response is most accurate? Under the stated engineering conditions, Using the controlling materials-engineering mechanism, fick's first law describes diffusion under which condition?

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

5. Apply the controlling metallurgical principle to this situation: For the stated material system and boundary conditions, tempering quenched martensitic steel primarily accomplishes which result?

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

6. In an alloy-development review, select the technically sound response: From the stated evidence and conditions, an edge dislocation is characterized by which feature?

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

7. A materials engineer investigating field behavior asks: A hypoeutectoid steel slowly cooled below the eutectoid temperature contains which constituents?

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

8. For the stated manufacturing condition, identify the best answer: For the described alloy and operating environment, which crystal structure has the highest atomic packing factor among the choices?

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

9. During interpretation of test results, which conclusion is correct? Under the stated engineering conditions, Applying the governing physical mechanism, 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

10. Apply the controlling metallurgical principle to this situation: During process qualification, which response is most accurate? Cross-linking a thermosetting polymer generally has which effect?

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

11. In an alloy-development review, select the technically sound response: Applying the relevant thermodynamic or kinetic principle, increasing temperature generally accelerates substitutional diffusion because it does what?

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

12. A materials engineer investigating field behavior asks: 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. Equiaxed dimples only
- D. River patterns crossing grains

13. For the stated manufacturing condition, identify the best answer: Given the available microstructural and operating evidence, in a BCC metal, the Burgers vector for a perfect dislocation is commonly of which type?

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

14. During interpretation of test results, which conclusion is correct? Under the stated engineering conditions, Applying the governing physical mechanism, Using the controlling materials-engineering mechanism, 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

15. Apply the controlling metallurgical principle to this situation: During process qualification, which response is most accurate? 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. Atomic radii differing by less than about 15 percent
- C. Large electronegativity differences
- D. Completely different valence states

16. In an alloy-development review, select the technically sound response: From the stated evidence and conditions, what does the lever rule determine in a two-phase region of a binary phase diagram?

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

17. A materials engineer investigating field behavior asks: Under the stated engineering conditions, Given the available microstructural and operating evidence, a high process capability index requires what relationship?

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

18. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, Which S-N curve feature defines fatigue endurance behavior?

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

19. During interpretation of test results, which conclusion is correct? During process qualification, which response is most accurate? Using the controlling materials-engineering mechanism, 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

20. Apply the controlling metallurgical principle to this situation: Ultrasonic pulse-echo inspection locates an internal reflector primarily from what measurement?

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

21. In an alloy-development review, select the technically sound response: From the stated evidence and conditions, for linear-elastic fracture mechanics, unstable crack growth begins when what occurs?

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

22. A materials engineer investigating field behavior asks: Under the stated engineering conditions, 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. Equal areas isolated electrically
- C. A small anode connected to a large cathode
- D. Two cathodes with no electrolyte

23. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, For the described alloy and operating environment, 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

24. During interpretation of test results, which conclusion is correct? During process qualification, which response is most accurate? Abrasive wear occurs primarily when what happens?

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

25. Apply the controlling metallurgical principle to this situation: Hydrogen embrittlement most directly reduces which property of a high-strength steel?

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

D. Thermal conductivity only

26. In an alloy-development review, select the technically sound response: For the described alloy and operating environment, recycling aluminum generally saves substantial energy compared with primary production because it avoids what?

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

27. A materials engineer investigating field behavior asks: Under the stated engineering conditions, A control chart point beyond a statistically established control limit most directly suggests what?

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

28. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, Applying the relevant thermodynamic or kinetic principle, during steady-state secondary creep, the strain rate is approximately what?

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

29. During interpretation of test results, which conclusion is correct? During process qualification, which response is most accurate? 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

30. Apply the controlling metallurgical principle to this situation: Under the stated engineering conditions, Given the available microstructural and operating evidence, magnetic-particle inspection can detect flaws in which materials?

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

31. In an alloy-development review, select the technically sound response: Fatigue beach marks on a fracture surface indicate what?

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

32. A materials engineer investigating field behavior asks: Using the controlling materials-engineering mechanism, 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

33. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, In failure analysis, preserving fracture surfaces before cleaning is essential because cleaning may do what?

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

34. During interpretation of test results, which conclusion is correct? During process qualification, which response is most accurate? From the stated evidence and conditions, charpy impact testing of ferritic steel is especially useful for identifying what?

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

35. Apply the controlling metallurgical principle to this situation: Under the stated engineering conditions, 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

36. In an alloy-development review, select the technically sound response: For the described alloy and operating environment, 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

37. A materials engineer investigating field behavior asks: During process qualification, which response is most accurate? Elastohydrodynamic lubrication is associated most closely with what contacts?

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

38. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, 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. Elastic unloading without time dependence
- D. Sustained stress at elevated homologous temperature

39. During interpretation of test results, which conclusion is correct? Thermal shock resistance of a brittle ceramic is generally improved by which property combination?

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

40. Apply the controlling metallurgical principle to this situation: Under the stated engineering conditions, 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

41. In an alloy-development review, select the technically sound response: A component subjected to a mean stress plus alternating stress is commonly assessed using which relation?

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

42. A materials engineer investigating field behavior asks: During process qualification, which response is most accurate? Using the controlling materials-engineering mechanism, 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. Compressive residual stress at the surface
- D. A thick brittle intermetallic layer

43. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, Radiographic testing is generally most sensitive to which flaw orientation?

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

44. During interpretation of test results, which conclusion is correct? From the stated evidence and conditions, plane-strain fracture toughness is generally lower than plane-stress toughness because plane strain has what?

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

45. Apply the controlling metallurgical principle to this situation: Under the stated engineering conditions, 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

46. In an alloy-development review, select the technically sound response: For the described alloy and operating environment, fitness-for-service assessment differs from simple code acceptance because it does what?

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

47. A materials engineer investigating field behavior asks: During process qualification, which response is most accurate? Adhesive wear and galling are promoted most strongly by which condition?

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

D. Hard particles suspended between surfaces

48. For the stated manufacturing condition, identify the best answer: Applying the governing physical mechanism, Applying the relevant thermodynamic or kinetic principle, a polymer exposed above its glass-transition temperature generally exhibits what change?

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

49. During interpretation of test results, which conclusion is correct? 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

50. Apply the controlling metallurgical principle to this situation: Applying the governing physical mechanism, Using the controlling materials-engineering mechanism, nitriding can produce a hard case with relatively low distortion because it commonly does what?

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

51. In an alloy-development review, select the technically sound response: Martempering reduces quench distortion by doing what?

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

52. A materials engineer investigating field behavior asks: From the stated evidence and conditions, 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

53. For the stated manufacturing condition, identify the best answer: Under the stated engineering conditions, Investment casting is selected when a component requires what?

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

54. During interpretation of test results, which conclusion is correct? During process qualification, which response is most accurate? For the described alloy and operating environment, cold working a ductile metal generally causes which property change?

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

55. Apply the controlling metallurgical principle to this situation: Applying the governing physical mechanism, Applying the relevant thermodynamic or kinetic 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. Acts as a sacrificial anode to exposed steel
- D. Raises the steel melting point

56. In an alloy-development review, select the technically sound response: Selective laser melting of metal powder requires control of energy density chiefly to avoid what tradeoff?

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

57. A materials engineer investigating field behavior asks: Given the available microstructural and operating evidence, carburizing a low-carbon steel component is used primarily to create what?

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

58. For the stated manufacturing condition, identify the best answer: Under the stated engineering conditions, Austempering steel is designed to produce predominantly which microstructure?

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

59. During interpretation of test results, which conclusion is correct? Gas porosity in an aluminum casting can be reduced by what action?

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

60. Apply the controlling metallurgical principle to this situation: Applying the governing physical mechanism, Using the controlling materials-engineering mechanism, in sand casting, a riser is designed primarily to do what?

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

61. In an alloy-development review, select the technically sound response: During process qualification, which response is most accurate? 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

62. A materials engineer investigating field behavior asks: From the stated evidence and conditions, applying the relevant thermodynamic or kinetic principle, 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

63. For the stated manufacturing condition, identify the best answer: Under the stated engineering conditions, Hot isostatic pressing improves a powder or casting by applying what?

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

64. During interpretation of test results, which conclusion is correct? 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

65. Apply the controlling metallurgical principle to this situation: Brazing differs from fusion welding because brazing does what?

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

66. In an alloy-development review, select the technically sound response: During process qualification, which response is most accurate? 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. 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

67. A materials engineer investigating field behavior asks: Applying the governing physical mechanism, Using the controlling materials-engineering mechanism, 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

68. For the stated manufacturing condition, identify the best answer: Under the stated engineering conditions, Differential scanning calorimetry measures what during a programmed temperature change?

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

69. During interpretation of test results, which conclusion is correct? From the stated evidence and conditions, 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

70. Apply the controlling metallurgical principle to this situation: 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

71. In an alloy-development review, select the technically sound response: During process qualification, which response is most accurate? For the described alloy and operating environment, quench severity is highest for which medium under typical conditions?

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

72. A materials engineer investigating field behavior asks: Applying the governing physical mechanism, 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. Nickel enrichment eliminates passivity in grain interiors
- C. Chromium carbide precipitation depletes chromium near grain boundaries
- D. Ferrite transforms completely to martensite

73. For the stated manufacturing condition, identify the best answer: Under the stated engineering conditions, In injection molding, insufficient holding pressure most directly promotes which defect?

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

D. Flash from excessive cavity pressure

74. During interpretation of test results, which conclusion is correct? Given the available microstructural and operating evidence, 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

75. Apply the controlling metallurgical principle to this situation: 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

76. In an alloy-development review, select the technically sound response: During process qualification, which response is most accurate? 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. Polymer chains cannot orient during extrusion
- D. Interlayer bonding differs from strength along deposited roads

77. A materials engineer investigating field behavior asks: Peak broadening in an X-ray diffraction pattern can indicate what?

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

78. For the stated manufacturing condition, identify the best answer: During process qualification, which response is most accurate? Using the controlling materials-engineering mechanism, 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

79. During interpretation of test results, which conclusion is correct? Under the stated engineering conditions, Applying the governing physical mechanism, A four-point electrical resistivity measurement reduces error from what?

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

80. Apply the controlling metallurgical principle to this situation: From the stated evidence and conditions, archimedes' method determines bulk density from what measurements?

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

81. In an alloy-development review, select the technically sound response: The linear-intercept method estimates grain size by counting what?

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

82. A materials engineer investigating field behavior asks: For the described alloy and operating environment, 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 elastic modulus
- B. Its atomic packing factor
- C. Its volume fraction in the material
- D. Its diffusion activation energy

83. For the stated manufacturing condition, identify the best answer: During process qualification, which response is most accurate? Metallographic etching reveals microstructure mainly by what mechanism?

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

84. During interpretation of test results, which conclusion is correct? Under the stated engineering conditions, Applying the governing physical mechanism, Given the available microstructural and operating evidence, salt-spray testing is best interpreted as what kind of test?

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

D. A direct measurement of fracture toughness

85. Apply the controlling metallurgical principle to this situation: 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 intersection or extrapolation of anodic and cathodic behavior
- D. The specimen's optical reflectivity

86. In an alloy-development review, select the technically sound response: For the stated material system and boundary conditions, 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

87. A materials engineer investigating field behavior asks: Fracture toughness testing requires a fatigue precrack primarily to provide what?

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

88. For the stated manufacturing condition, identify the best answer: During process qualification, which response is most accurate? Using the controlling materials-engineering mechanism, 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

89. During interpretation of test results, which conclusion is correct? Under the stated engineering conditions, Applying the governing physical mechanism, A strain gauge aligned with the loading direction measures which quantity directly?

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

90. Apply the controlling metallurgical principle to this situation: From the stated evidence and conditions, 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. Elastic recovery area
- D. Original cross-sectional area

91. In an alloy-development review, select the technically sound response: 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. Yield strength when no sharp yield point exists
- D. Ultimate strength after necking only

92. A materials engineer investigating field behavior asks: For the described alloy and operating environment, the Vickers hardness number is calculated using what?

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

93. For the stated manufacturing condition, identify the best answer: During process qualification, which response is most accurate? Under the stated engineering conditions, 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

94. During interpretation of test results, which conclusion is correct? Applying the governing physical mechanism, Dynamic mechanical analysis of a polymer measures what response?

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

95. Apply the controlling metallurgical principle to this situation: Thermogravimetric analysis records which quantity as temperature or time changes?

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

96. In an alloy-development review, select the technically sound response: For the described alloy and operating environment, 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. Characteristic wavelengths emitted by excited atoms
- C. Indentation depth under a known force
- D. Heat flow during melting

97. A materials engineer investigating field behavior asks: Electron backscatter diffraction is used chiefly to map what?

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

98. For the stated manufacturing condition, identify the best answer: During process qualification, which response is most accurate? Under the stated engineering conditions, 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. Magnetic domains become permanently aligned
- C. Electrons transmit through the material
- D. The specimen remains at its melting point

99. During interpretation of test results, which conclusion is correct? Applying the governing physical mechanism, In SEM-based energy-dispersive spectroscopy, characteristic X-rays reveal what?

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

100. Apply the controlling metallurgical principle to this situation: For the stated material system and boundary conditions, scanning electron microscopy is especially useful for examining what?

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

Practice Exam 19: Answer Key and Explanations

1. C — 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.

2. A — 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.

3. B — 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.

4. D — 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.

5. B — 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.

6. C — 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.

7. A — 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.

8. D — 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.

9. 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.

10. B — 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.

11. C — 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.

12. D — 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.

13. A — 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.

14. 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.

15. B — 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.

16. C — 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.

17. D — 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.

18. B — 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.

19. 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.

20. C — 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.

21. B — 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.

22. C — 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.

23. 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.

24. A — 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.

25. C — 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.

26. A — 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.

27. B — 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.

28. D — 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.

29. 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.

30. A — 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.

31. D — 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.

32. 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.

33. A — 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.

34. C — 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.

35. 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.

36. 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.

37. B — 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.

38. D — 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.

39. C — 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.

40. 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.

41. A — 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.

42. C — 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.

43. B — 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.

44. D — 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.

45. 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.

46. D — 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.

47. C — 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.

48. A — 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.

49. 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.

50. B — 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.

51. C — 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.

52. 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.

53. B — 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.

54. D — 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.

55. C — 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.

56. A — 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.

57. A — 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.

58. C — 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.

59. B — 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.

60. D — 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.

61. 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.

62. A — 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.

63. C — 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.

64. 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.

65. D — 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.

66. B — 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.

67. 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.

68. C — 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.

69. 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.

70. 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.

71. B — 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.

72. C — 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.

73. C — 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.

74. A — 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.

75. 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.

76. D — 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.

77. B — 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.

78. 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.

79. D — 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.

80. C — 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.

81. B — 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.

82. C — 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.

83. D — 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.

84. A — 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.

85. C — 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.

86. D — 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.

87. A — 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.

88. 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.

89. A — 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.

90. D — 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.

91. C — 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.

92. B — 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.

93. 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.

94. C — 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.

95. D — 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.

96. B — 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.

97. B — 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.

98. C — 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.

99. A — 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.

100. D — 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.