PRACTICE EXAM 18: STATIONARY ENGINEER (ELECTRIC) SIMULATION — 100 QUESTIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. The total resistance of a series circuit with resistors of 12Ω, 18Ω, and 30Ω is?

A. 7.2Ω

B. 60Ω

C. 20Ω

D. 15Ω

2. Ohm's Law states that current in a DC circuit is equal to?

A. Voltage divided by resistance

B. Resistance divided by voltage

C. Voltage multiplied by resistance

D. Power divided by resistance

3. A 240V, single-phase load draws 15A at a power factor of 0.75 lagging. The reactive power (VAR) is?

A. 1,350 VAR

B. 2,700 VAR

C. 1,800 VAR

D. 2,025 VAR

4. The unit of electrical capacitance is the?

A. Henry

B. Weber

C. Farad

D. Siemens

5. In a transformer, increasing the number of secondary turns while keeping the primary turns constant will?

A. Decrease the secondary voltage

B. Keep the secondary voltage unchanged

C. Decrease the primary current

D. Increase the secondary voltage

6. Two inductors of 8H and 4H are connected in series with no mutual coupling. The total inductance is?

A. 2.67H

B. 12H

C. 4H

D. 32H

7. The phase angle between voltage and current in a purely resistive AC circuit is?

A. 0° — voltage and current are in phase

B. 90° lagging

C. 45° leading

D. 90° leading

8. In a DC circuit, a voltmeter should be connected?

A. In series with the component being measured

B. Between the source terminals only

C. In parallel with the component being measured

D. In series with the ammeter

9. The term "skin effect" in AC conductors refers to?

A. Corrosion on the outer surface of conductors

B. The tendency of AC current to flow predominantly on the outer surface of a conductor — increasing effective resistance above the DC resistance at higher frequencies

C. Insulation degradation from UV exposure

D. The temperature gradient across the conductor cross-section

10. A 1 kΩ resistor and a 0.1μF capacitor are connected in series. At 1,592 Hz, the circuit impedance is approximately?

A. 1,592Ω

B. 1,414Ω

C. 1,000Ω

D. 2,000Ω

11. The purpose of a varistor (MOV) in an electrical circuit is to?

A. Regulate voltage to a precise level regardless of load changes

B. Clamp transient overvoltages by becoming low-resistance when voltage exceeds its rated clamping voltage

C. Filter high-frequency noise from the supply voltage

D. Provide current-limiting protection for sensitive equipment

12. In a balanced three-phase system, the phasors of the three phase voltages sum to?

A. The line-to-line voltage

B. Three times the phase voltage

C. Zero

D. The neutral voltage

WIRING, CONDUCTORS, AND PROTECTIVE DEVICES (Questions 13–22)

13. Per NEC 240.6, which of the following is a standard ampere rating for overcurrent devices?

A. 45A

B. 40A

C. 55A

D. 65A

14. The purpose of NEC Article 230's service entrance conductor requirements is to?

A. Ensure service conductors from the utility connection to the service disconnect are adequately sized and protected — meeting the minimum requirements for the point where utility power enters the building

B. Define conductor sizing for feeders from the main panel to subpanels

C. Establish requirements for underground service lateral conductors only

D. Define the requirements for utility-owned service conductors

15. Under NEC 300.3(B), all conductors of a circuit must be in the same raceway, cable, or trench because?

A. It simplifies conductor identification and maintenance

B. Keeping all circuit conductors together allows magnetic fields from individual conductors to cancel — preventing inductive heating of metal enclosures and reducing impedance of the fault current return path

C. It reduces the number of conduit supports required

D. It prevents crosstalk between circuits in adjacent conduits

16. The purpose of a listed "self-resetting" GFCI receptacle vs. a standard GFCI is to?

A. Automatically restore power after a ground fault is cleared — eliminating the need for manual reset after nuisance trips, used in locations where manual reset access is difficult such as underground or outdoor locations

B. Provide faster tripping response than a standard GFCI

C. Allow higher fault current before tripping

D. Provide dual protection for both phase-to-ground and phase-to-neutral faults

17. Per NEC 408.3(F), the neutral bus in a subpanel fed from a separate building must be?

A. Connected to the ground bus and equipment grounding conductor

B. Connected to the grounding electrode at the subpanel

C. Bonded to the enclosure at the subpanel

D. Isolated from the equipment ground and enclosure — the neutral-ground bond is made only at the main service panel, not at remote distribution panels

18. The ampacity correction factor for conductors installed in an ambient temperature of 50°C using 75°C-rated conductors per NEC Table 310.15(B)(1) is?

A. 0.75

B. 0.88

C. 0.82

D. 0.94

19. The purpose of NEC 210.52(G) requiring a receptacle in a bathroom is to?

A. Power electric toothbrushes and shavers only

B. Provide convenience outlets for personal care appliances only

C. Ensure a conveniently located, GFCI-protected outlet is available in every bathroom — reducing the hazard from extension cords run from other rooms near water

D. Satisfy OSHA requirements for employee restroom electrical access

20. Under NEC 225.30, a building or structure that is served from more than one branch circuit, feeder, or service must have all feeders or branch circuits from a?

A. Single metering point at the utility transformer

B. Panel with a main disconnect rated for the total load

C. Single service entrance point at the building

D. Single source or where multiple sources are permitted by the exceptions — ensuring a single point of disconnect for all power to the building

21. The purpose of a "listed" equipment bonding jumper (EBJ) at a service panel is to?

A. Connect the grounded conductor to the equipment ground at the service disconnect — establishing the neutral-ground bond that allows fault current to return to the source and operate the overcurrent device

B. Bond the service panel to the grounding electrode system

C. Connect the grounding electrode conductor to the neutral bus

D. Provide a secondary path for lightning current to ground

22. The minimum cover requirement for direct-buried cables listed for direct burial under a concrete slab per NEC Table 300.5 is?

A. 0 inches — the concrete provides protection

B. 6 inches below the concrete

C. 12 inches below the concrete

D. 24 inches minimum regardless of cover

POWER DISTRIBUTION AND HIGH-TENSION SYSTEMS (Questions 23–32)

23. The purpose of a "distance relay" (ANSI 21) in transmission line protection is to?

A. Protect against overload conditions on long transmission lines

B. Provide backup ground fault protection for the transmission line

C. Monitor the temperature of transmission line conductors for sag control

D. Measure the apparent impedance to a fault and trip when the impedance falls within a preset zone — providing high-speed line protection proportional to the electrical distance to the fault

24. In a power system, the term "X/R ratio" at a fault point affects equipment ratings because?

A. Higher X/R ratios produce greater DC offset in the fault current — increasing the peak asymmetrical current that switching devices, buses, and conductors must withstand during the first few cycles after fault inception

B. Lower X/R ratios increase the steady-state fault current magnitude

C. X/R ratio determines the relay operating time for overcurrent relays

D. Higher X/R ratios reduce the available fault current at the fault point

25. The purpose of a power system "voltage regulation" specification for a transformer is to?

A. Define the maximum harmonic distortion permitted on the secondary voltage

B. Specify the transformer's efficiency at full load

C. Define the percentage change in secondary voltage from no-load to full-load — a lower VR% indicates the transformer maintains more constant output voltage under varying load conditions

D. Specify the maximum primary voltage variation the transformer can tolerate

26. In a high-voltage substation, "bus differential protection" (ANSI 87B) operates by?

A. Measuring the voltage differential between adjacent bus sections

B. Detecting temperature rise in the bus bars indicating overload

C. Comparing the sum of all currents entering and leaving the bus — a differential current above the pickup indicates a fault on the bus itself, producing high-speed tripping of all connected breakers

D. Monitoring insulator leakage current for early fault detection

27. The purpose of a "capacitor bank" installed on a distribution feeder is to?

A. Provide voltage support during peak load periods only

B. Supply reactive power locally — reducing reactive current flow on the feeder, improving voltage profile, reducing feeder losses, and releasing capacity for additional real power loads

C. Filter harmonic currents generated by nonlinear loads on the feeder

D. Provide backup power during brief utility outages

28. In a protective relaying scheme, "coordination" means?

A. Multiple relays operating simultaneously to clear a fault faster

B. Sequencing relay operating times so the device closest to the fault trips first — leaving the maximum amount of the system energized after a fault is cleared

C. All relays in a system being set to the same current pickup value

D. Backup relays operating simultaneously with primary relays

29. The purpose of a "neutral grounding resistor" (NGR) on a medium-voltage generator is to?

A. Improve generator power factor during lagging load operation

B. Limit generator fault current to rated values during overload

C. Reduce generator harmonic distortion on the distribution system

D. Limit the ground fault current to a low value (typically 1–10A) — allowing the system to continue operating with a single line-to-ground fault while limiting fault damage and providing time for controlled shutdown

30. A 15 MVA, 13.8kV/4.16kV transformer has a percent impedance of 6%. The available secondary fault current is approximately?

A. 8,200A

B. 34,800A

C. 5,830A

D. 11,500A

31. The purpose of a "transfer bus" arrangement in a substation is to?

A. Allow any feeder breaker to be removed for maintenance by transferring its circuit to the transfer bus — maintaining service continuity without interrupting the load

B. Provide a backup bus for emergency operation when the main bus is faulted

C. Connect the substation to an alternate utility source

D. Separate high-voltage and low-voltage bus sections

32. In a medium-voltage switchgear lineup, the purpose of the "primary injection" test during commissioning is to?

A. Verify the complete protection system from CT primary through relay to breaker trip — using a high-current test set to inject current through the CT primary and confirm the relay operates and trips the breaker at the correct current and time

B. Test the switchgear insulation at twice rated voltage

C. Verify bus bar connections are tight before energization

D. Test the breaker interrupting capacity at rated voltage

GENERATORS, MOTORS, AND MOTOR CONTROL (Questions 33–44)

33. The purpose of a generator's "loss of field" relay (ANSI 40) is to?

A. Detect generator overloading from connected motor loads

B. Protect generator step-up transformer from overvoltage

C. Monitor generator stator winding temperature for overload

D. Detect loss of excitation — an unexcited generator absorbs reactive power from the system and may pull out of synchronism, damaging the rotor from eddy current heating

34. A 3-phase, 4160V, 500 HP synchronous motor has a rated full-load current of approximately?

A. 58A

B. 72A

C. 46A

D. 84A

35. The purpose of a motor's "code letter" on its nameplate (A through V) is to?

A. Identify the motor's NEMA frame size for mechanical mounting

B. Define the motor's insulation class and temperature rating

C. Indicate the motor's efficiency classification under EISA 2007

D. Specify the locked rotor kVA per horsepower — used to select the correct branch circuit overcurrent protection per NEC Table 430.52

36. In a DC shunt motor, if the field circuit opens while the motor is running under light load, the motor will?

A. Stall immediately due to loss of field flux

B. Runaway — flux drops to residual value only, back-EMF drops, armature current increases dramatically, and the motor accelerates to potentially destructive speed

C. Operate at reduced speed with increased current

D. Trip the overload relay due to increased armature current

37. The purpose of a "reactor" (line reactor) installed on the input side of a VFD is to?

A. Prevent overvoltage on the DC bus during regenerative braking

B. Filter harmonic currents generated in the motor by the PWM output

C. Reduce harmonic currents drawn from the supply, limit fault current into the VFD, and protect the drive from voltage transients — also improving the VFD's input power factor

D. Provide a path for DC bus discharge when the drive is powered down

38. A 480V, 3-phase motor nameplate shows: FLA = 28A, SF = 1.15, code letter G. Per NEC 430.32, the maximum overload relay setting for this motor is?

A. 28A

B. 32.2A

C. 35A

D. 40.6A

39. The purpose of a "power factor correction" capacitor bank at a motor's terminals is to?

A. Increase the motor's output horsepower rating

B. Reduce motor winding temperature during operation

C. Improve the motor's speed regulation under variable load

D. Supply reactive magnetizing current locally — reducing reactive current drawn from the supply, improving the facility's power factor and reducing utility demand charges

40. The purpose of a motor's "starting torque" specification is to?

A. Define the torque available at zero speed when full voltage is applied — determining whether the motor can start and accelerate a specific load from rest

B. Specify the maximum torque before the motor pulls out of synchronism

C. Define the torque available at rated speed and full load

D. Specify the torque during the star-to-delta transition in reduced voltage starting

41. In a VFD application, "carrier frequency" (switching frequency) selection involves a tradeoff between?

A. Motor speed range and available torque at low speed

B. VFD output voltage and the DC bus ripple voltage

C. Motor acoustic noise (higher carrier = quieter) and VFD IGBT heating (higher carrier = more switching losses and heat)

D. Motor efficiency and drive output harmonic distortion

42. The purpose of a "contactor" vs. a "circuit breaker" in motor starting is that a contactor?

A. Provides both overcurrent protection and switching in a single device

B. Is rated for frequent switching (millions of operations) and designed to be controlled by low-power pilot signals — while a circuit breaker is designed for infrequent operation and overcurrent interruption

C. Interrupts fault current more effectively than a circuit breaker

D. Requires no maintenance throughout its service life

43. A three-phase motor running at 1,760 RPM on a 60Hz, 4-pole supply has a percent slip of?

A. 4.0%

B. 2.2%

C. 1.1%

D. 3.3%

44. The purpose of a "motor protection relay" (MPR) vs. a traditional bimetallic overload relay is that an MPR?

A. Provides only thermal overload protection identical to a bimetallic relay

B. Responds faster to overload conditions than a bimetallic relay

C. Provides comprehensive protection including thermal overload, phase loss, phase unbalance, ground fault, locked rotor, and undercurrent — with programmable settings, event logging, and communication capability

D. Is required by NEC for all motors above 100 HP

ELECTRICAL TESTING, TROUBLESHOOTING, AND MAINTENANCE (Questions 45–54)

45. The purpose of a "power quality analyzer" installed on a facility's main service is to?

A. Monitor utility billing data for demand charge verification

B. Continuously record voltage, current, frequency, harmonics, flicker, and power factor — identifying power quality disturbances that cause equipment malfunctions, overheating, or premature failure

C. Detect ground faults on individual branch circuits

D. Provide remote monitoring of service entrance metering data

46. When a 480V motor trips immediately on overload at the moment of starting but runs normally when restarted, the most likely cause is?

A. Momentary voltage dip on the supply bus during the start of a large adjacent motor — reducing available starting torque and increasing starting time, causing the overload relay to trip on locked rotor time

B. The motor windings are overheated from a previous start

C. A loose connection in the motor terminal box

D. The overload relay has failed

47. The purpose of a "winding resistance" test on a transformer is to?

A. Measure transformer insulation resistance between windings

B. Detect high-resistance connections, open circuits, or shorted turns — by comparing measured resistance values on all windings against nameplate data and between phases

C. Verify transformer polarity and connection configuration

D. Measure transformer core losses at no load

48. When performing a megohmmeter test on a 4,160V motor, the test voltage and minimum acceptable IR at the end of the test should be?

A. 500V DC, minimum 1 MΩ

B. 1,000V DC, minimum 10 MΩ

C. 2,500V DC, minimum 50 MΩ

D. 2,500V DC — IEEE 43-2013 recommends 2,500V test voltage for motors 2,401–5,000V; minimum acceptable IR = 100 MΩ for motors in service (lower values may warrant investigation)

49. The purpose of a "thermal imaging" (IR) survey on a low-voltage switchboard is best scheduled?

A. During shutdown with all breakers open for safe access

B. At light load — below 25% of rated load for maximum sensitivity

C. During night shift when ambient temperature is lowest

D. At or above 40% of rated load — thermal anomalies from loose connections, overloaded conductors, and failing components are only detectable when significant current is flowing to generate measurable heat differentials

50. A power factor test on a medium-voltage cable shows a power factor of 3.2% at operating voltage. This result indicates?

A. The cable is in excellent condition — any PF below 5% is acceptable

B. Insulation deterioration — new cable power factor is typically below 0.5%; 3.2% indicates significant aging, moisture ingress, or contamination requiring investigation and potential cable replacement

C. The test was performed at incorrect voltage

D. Normal cable condition for cables in service more than 10 years

51. The purpose of a "circuit tracer" tool in an industrial facility is to?

A. Identify the source of harmonic disturbances on the power system

B. Locate the routing and identify the correct circuit breaker for an unknown circuit — using a signal injected on the circuit that a receiver can detect through walls, floors, and panels

C. Test ground fault protection by injecting a test fault signal

D. Trace the path of fault current during a ground fault event

52. When a transformer's differential relay operates but no internal fault is found upon inspection, a common cause is?

A. The transformer is overloaded beyond its nameplate kVA rating

B. CT mismatch or incorrect CT polarity wiring — producing a spurious differential current that appears as an internal fault to the relay even during normal through-load conditions

C. A momentary external fault that self-cleared before the transformer was inspected

D. The relay setpoint is set too sensitively for the transformer's magnetizing inrush current

53. The purpose of a "doble test" (power factor test) on a transformer bushing is to?

A. Measure the bushing's flashover voltage under wet conditions

B. Detect deterioration of the bushing's condenser insulation

C. Verify the bushing current rating under full-load conditions

D. Measure the bushing's creepage distance for pollution level assessment

54. When troubleshooting a VFD that displays an "output phase loss" fault, the first check should be?

A. Measure DC bus voltage with a multimeter

B. Verify continuity and connection integrity of all three output phases from the VFD terminals to the motor — an open connection or failed IGBT in one phase produces this fault

C. Check the VFD's input phase voltages for balance

D. Inspect the motor stator windings with a megohmmeter

MECHANICAL EQUIPMENT (Questions 55–63)

55. The purpose of a "variable frequency drive" (VFD) on a centrifugal pump vs. a throttling valve for flow control is that a VFD?

A. Provides more precise flow control than throttling

B. Reduces pump energy consumption proportionally to the cube of speed reduction — throttling wastes energy by adding artificial resistance while the pump runs at full speed

C. Eliminates the need for a pump discharge check valve

D. Reduces pump maintenance by eliminating mechanical seal wear

56. In a steam system, the "critical pressure ratio" across a steam trap orifice determines?

A. The maximum steam pressure the trap can handle

B. The minimum differential pressure required for the trap to open

C. Whether steam flow through the orifice is sonic (choked) or subsonic — above the critical pressure ratio, flow is independent of downstream pressure

D. The trap's steam loss rate in pounds per hour

57. The purpose of a boiler's "refractory" lining is to?

A. Provide the primary pressure-containing structure of the furnace

B. Absorb and store heat during startup for faster temperature response

C. Reflect radiant heat back into the furnace to improve combustion efficiency and protect the steel furnace casing from high-temperature flue gases

D. Filter particulates from combustion gases before they contact heat transfer surfaces

58. In a hydraulic system, "cavitation" in a hydraulic pump is caused by?

A. Inlet restriction creating a vacuum that causes fluid to vaporize at the pump inlet — vapor bubbles collapse violently in the higher-pressure region, eroding pump components and generating noise

B. Excessive discharge pressure exceeding the relief valve setpoint

C. Air injection into the hydraulic fluid during system filling

D. High fluid viscosity causing sluggish valve response

59. The purpose of a centrifugal pump's "wear rings" (case rings and impeller rings) is to?

A. Minimize leakage between the high-pressure discharge and low-pressure suction — limiting internal recirculation that reduces pump efficiency; worn rings reduce head and efficiency

B. Protect the impeller from cavitation damage

C. Support the impeller on the pump shaft

D. Prevent abrasive particles in the fluid from reaching the mechanical seal

60. In a reciprocating compressor, "valve efficiency" is defined as the ratio of?

A. Actual discharge pressure to theoretical discharge pressure

B. Indicated horsepower to brake horsepower

C. Actual volumetric efficiency to theoretical volumetric efficiency — accounting for valve pressure drop, leakage through valves, and delayed valve opening/closing

D. Actual power consumed to the theoretical minimum power for the compression ratio

61. The purpose of a turbine's "diaphragm" between stages is to?

A. Separate the wet and dry steam zones in the turbine casing

B. Contain the nozzle passages that accelerate steam into the rotating blades of each stage — converting steam pressure drop to high-velocity jets that transfer energy to the moving blades

C. Support the turbine rotor at each stage

D. Provide the expansion joint between turbine casing sections

62. In a refrigeration system, "subcooling" of liquid refrigerant before the expansion valve?

A. Reduces compressor discharge temperature

B. Prevents flash gas formation in the liquid line

C. Reduces condenser pressure by lowering refrigerant temperature

D. Increases the refrigerant's enthalpy drop across the expansion valve — increasing the refrigerating effect per pound of refrigerant circulated and improving system efficiency

63. The purpose of a pump's "volute casing" design vs. a "diffuser" design is that a volute?

A. Converts the kinetic energy of the fluid leaving the impeller to pressure through a gradually expanding spiral passage — the increasing area decelerates the fluid and recovers pressure

B. Provides higher efficiency at all flow rates

C. Eliminates radial thrust on the pump shaft

D. Allows easier adjustment of the pump's operating point

FLUID SYSTEMS (Questions 64–72)

64. The purpose of a "cooling tower" bypass valve in a chilled water plant during cold weather is to?

A. Divert tower basin water to the chiller sump during freeze conditions

B. Allow the cooling tower to be isolated for winter maintenance

C. Prevent ice formation on the cooling tower fill media

D. Maintain minimum condenser water temperature entering the chiller by blending warm condenser water return with cold tower water — preventing chiller low-condenser-pressure faults

65. In a steam distribution system, "pressure drop" along a steam main is caused by?

A. Steam condensation only — all pressure drop results from heat loss

B. Pipe friction only — condensation does not affect pressure

C. Thermal expansion of the steam main absorbing steam pressure

D. Friction losses in the piping, fittings, and valves plus the momentum effect of condensation — both reduce available steam pressure at the end of the main

66. The purpose of a "two-pipe" hydronic heating system vs. a "one-pipe" system is that a two-pipe system?

A. Uses twice as much pipe — increasing material and installation cost

B. Allows only two terminal units to operate simultaneously

C. Supplies all terminal units with full supply temperature water and returns water directly to the boiler — eliminating the progressive temperature drop that limits the capacity of the last terminal units in a one-pipe series loop

D. Is required only for systems above 200 MBH output

67. The purpose of a compressed air system's "air receiver" (storage tank) is to?

A. Remove oil from compressed air before distribution

B. Filter moisture from the compressed air supply

C. Dampen compressor cycling frequency, absorb pulsations from reciprocating compressors, provide surge capacity for brief peak demands, and allow the system to continue operating briefly during compressor shutdown

D. Regulate the system pressure automatically without the compressor running

68. In a building HVAC system, "economizer" operation uses outdoor air for cooling when?

A. Outdoor temperature is below the indoor setpoint regardless of humidity

B. The HVAC system is in heating mode and outdoor air is used to pre-heat supply air

C. The building is unoccupied and outdoor air is used to flush the building of overnight off-gassing

D. Outdoor air conditions (temperature and/or enthalpy) are favorable enough that outdoor air can provide free cooling — reducing or eliminating the need for mechanical refrigeration

69. The purpose of a boiler's "safety valve" vs. a "relief valve" is that a safety valve?

A. Opens fully and rapidly (pop action) when set pressure is reached — designed for compressible fluid (steam) service where a gradual opening would create an unstable condition; a relief valve opens gradually proportional to overpressure, designed for liquid service

B. Is set at a lower pressure than the relief valve

C. Provides backup protection only if the relief valve fails

D. Is tested monthly while the relief valve is tested annually

70. In a chilled water system, "free cooling" (waterside economizer) operation uses?

A. Outdoor air directly to cool the building without refrigeration

B. Building exhaust air to pre-cool outdoor ventilation air

C. Cooling tower water, cooled to below the required chilled water supply temperature during cold weather, to cool the building without operating the chiller — circulating tower water directly or indirectly through a heat exchanger to the chilled water loop

D. Ground source heat exchange loops for cooling during shoulder seasons

71. The purpose of a steam system's "vacuum return" vs. a "gravity return" condensate system is that a vacuum return?

A. Operates at negative pressure throughout the return system — allowing condensate to drain against gravity, overcoming back pressure from steam traps, and reducing the minimum steam pressure required at terminal units

B. Is only used for condensate return distances exceeding 500 feet

C. Eliminates the need for steam traps throughout the system

D. Is used exclusively for high-pressure steam systems above 150 psig

72. The purpose of a chiller plant's "condenser water treatment program" is to?

A. Maintain proper condenser water chemistry — controlling scale, corrosion, biological growth (Legionella), and fouling to protect condenser tubes, cooling tower fill, and basin from deterioration and to maintain heat transfer efficiency

B. Remove refrigerant from condenser water in case of tube leaks

C. Reduce condenser water temperature below the cooling tower design temperature

D. Monitor condenser water flow for pump performance trending

CONSTRUCTION, TOOLS, AND RIGGING (Questions 73–80)

73. The purpose of a "rotary hammer drill" vs. a standard drill for anchoring in concrete is that a rotary hammer?

A. Provides higher torque for driving large anchor bolts

B. Uses a water-cooled bit to prevent concrete overheating

C. Drills at lower RPM to prevent concrete cracking

D. Combines rotation with impact blows — breaking the concrete progressively with each blow rather than relying solely on abrasion, dramatically increasing drilling speed and reducing bit wear in hard concrete

74. When installing a compression lug on a large conductor (350 kcmil and above), the correct procedure includes?

A. Using a hydraulic crimper set to the manufacturer's specified die and applying crimps starting from the conductor end toward the barrel opening — to prevent conductor strand flaring and air pockets

B. Heating the lug with a torch before crimping to soften the barrel

C. Applying multiple crimps in random order across the barrel

D. Using a mechanical crimper for large conductors — hydraulic crimpers are only for conductors below 4/0

74. When installing a compression lug on a large conductor (350 kcmil), the correct crimping procedure is to?

A. Consult the connector manufacturer's installation specification — apply crimps in the correct location, number, and sequence using the manufacturer-specified die to produce a verified low-resistance connection

B. Apply as many crimps as possible for maximum contact area

C. Use the largest available die for additional compression

D. Begin crimping from the open end of the barrel toward the conductor tip — to compress air out of the barrel

75. The purpose of a "come-along" chain vs. a "wire rope come-along" in heavy rigging is that a chain come-along?

A. Is lighter and easier to use in confined spaces

B. Provides better resistance to sharp edges and heat — chain does not fatigue from bending over sheaves or cutting on sharp metal edges, making it preferable near hot equipment or sharp-edged loads

C. Has a higher speed ratio for faster load movement

D. Is required for all overhead lifting by OSHA regulations

76. The purpose of a "personnel fall arrest system" (PFAS) vs. a "fall restraint system" is that a PFAS?

A. Prevents a worker from reaching a fall hazard — the lanyard length limits movement so the worker cannot reach the edge

B. Arrests a fall after it begins — limiting free fall to 6 feet, limiting arrest force to 1,800 lbs, and stopping the worker before striking a lower level

C. Is only required for heights above 10 feet in general industry

D. Uses a body belt as the connecting component for the worker

77. When performing conduit bending for a 3-bend saddle over a 2-inch obstruction, the center bend angle is?

A. 22.5°

B. 45°

C. 90°

D. The center bend is twice the angle of the two outer bends — for a 2-inch saddle with 22.5° outer bends, the center bend is 45°

78. The purpose of a "hydraulic torque wrench" vs. a standard torque wrench for large bolt tightening is that a hydraulic torque wrench?

A. Measures bolt tension directly rather than applied torque

B. Applies precise, calibrated torque to large fasteners (above the range of manual torque wrenches) using hydraulic pressure — used for large flange bolting, transformer terminal connections, and bus bar joints requiring 500+ ft-lbs

C. Is required for all bolted bus bar connections in switchgear

D. Provides impact torque rather than steady rotational force

79. The purpose of a "ground fault passage indicator" (GFPI) installed on distribution feeders in a facility is to?

A. Trip the feeder circuit breaker automatically when a ground fault is detected

B. Detect and indicate the passage of ground fault current on a feeder segment — allowing maintenance staff to quickly identify which feeder branch or zone contains the fault without de-energizing the entire system

C. Measure ground fault current magnitude for relay coordination studies

D. Provide GFCI protection for all branch circuits fed from the feeder

80. When cutting conduit with a conduit cutter (wheel cutter) rather than a hacksaw, the key advantage is?

A. Produces a square cut without burring the conduit OD

B. Works effectively on both rigid metal and non-metallic conduit

C. Requires less physical effort than hacksawing large conduit

D. Produces a perfectly square, consistent cut that seats properly in couplings and connectors — however the conduit must be reamed after cutting to remove the internal bead that the cutter wheel creates

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. The purpose of OSHA's "globally harmonized system" (GHS) implementation in HazCom 2012 is to?

A. Replace the MSDS system with SDSs having a standardized 16-section format and standardized pictograms — harmonizing chemical hazard communication across international trade and ensuring consistent hazard information regardless of where the chemical originates

B. Eliminate the need for container labeling for chemicals below 1 gallon

C. Satisfy EPA requirements for toxic chemical reporting under SARA Title III

D. Provide emergency response information exclusively for first responders

82. Under OSHA 1910.119 (PSM), the "process hazard analysis" (PHA) must be revalidated every?

A. 5 years — using a team with engineering and process operations expertise to review the current process against the previous PHA, incorporating any changes, near misses, and incidents that have occurred

B. 3 years for processes above 10,000 lbs of flammable materials

C. 10 years from the original PHA date

D. At the facility's discretion based on process change frequency

83. The purpose of EPA's "Risk Management Program" (RMP) under CAA Section 112(r) is to?

A. Replace OSHA PSM requirements for facilities covered by both programs

B. Require facilities to submit emissions inventories for regulated substances

C. Require facilities handling regulated substances above threshold quantities to assess worst-case and alternative release scenarios, implement prevention programs, and prepare emergency response plans — sharing this information with local emergency planners and the public

D. Establish permit requirements for air emissions from industrial facilities

84. Under RCRA, the "land disposal restrictions" (LDR) program requires?

A. Hazardous wastes to be treated to specified standards before land disposal — preventing untreated hazardous constituents from contaminating groundwater through land disposal facilities

B. All hazardous waste to be incinerated rather than landfilled

C. Hazardous waste generators to install groundwater monitoring at their facilities

D. EPA approval before any hazardous waste is transported off-site

85. The purpose of a facility's "emergency planning and community right-to-know" (EPCRA) Tier II report is to?

A. Report accidental chemical releases to the state emergency response commission

B. Notify the local fire department of all chemicals stored at the facility

C. Report chemical inventories above threshold quantities to the SERC, LEPC, and local fire department — providing emergency responders with information about the types, quantities, and locations of hazardous chemicals at the facility

D. Satisfy EPA TRI reporting requirements for toxic chemical releases

86. The purpose of OSHA's "respiratory protection program" under 1910.134 requires a facility to?

A. Provide respirators to all employees working near any chemical regardless of exposure level

B. Conduct annual respirator fit testing for all employees

C. Satisfy NIOSH certification requirements for all supplied-air respirators

D. Provide a written program, conduct exposure assessments, select appropriate respirators, train employees, and perform medical evaluations — ensuring respirators are effective and not worn unnecessarily when engineering controls could eliminate the exposure

87. Under the Clean Air Act, a "Title V major source" permit consolidates?

A. All applicable CAA requirements into a single, federally enforceable operating permit — providing a comprehensive document that specifies all emission limits, monitoring, recordkeeping, and reporting requirements applicable to the facility

B. Permits from multiple state environmental agencies into a single federal document

C. Air quality permits with water discharge permits for facilities with both types

D. CAA requirements with RCRA requirements for multi-media facilities

88. The purpose of OSHA's "bloodborne pathogens" standard (1910.1030) as it applies to industrial first aid programs is to?

A. Require all industrial facilities to employ a licensed nurse

B. Establish requirements for facilities with medical clinics only

C. Provide first aid training requirements for all employees

D. Protect employees designated as first aid responders from exposure to blood and OPIM — requiring hepatitis B vaccination, PPE, training, post-exposure protocols, and recordkeeping for exposure incidents

89. The purpose of "environmental due diligence" (Phase I ESA) before purchasing industrial property is to?

A. Identify recognized environmental conditions (RECs) — evidence of existing or potential contamination that could create liability for the new owner — allowing the purchaser to evaluate the risk and negotiate liability allocation before the transaction closes

B. Satisfy EPA permit transfer requirements when purchasing operating facilities

C. Document current environmental compliance status for the facility's permit files

D. Conduct soil and groundwater sampling to confirm contamination levels

SAFETY, LOTO, ARC FLASH, AND EMERGENCY PROCEDURES (Questions 90–100)

90. Under NFPA 70E 130.5(G), arc flash PPE is not required when?

A. Working on circuits below 120V regardless of available fault current

B. The equipment is in an electrically safe work condition (ESWC) — de-energized, locked out, and verified — eliminating the arc flash hazard entirely

C. A qualified person determines the arc flash hazard is acceptable

D. The available incident energy is below 1.2 cal/cm²

91. The purpose of "voltage-rated tools" (insulated hand tools) per NFPA 70E 130.6(D) is to?

A. Replace the need for rubber insulating gloves when working on energized circuits

B. Reduce the risk of inadvertent contact with energized parts and provide a secondary layer of insulation protection — they are used in addition to, not instead of, appropriate rubber insulating gloves

C. Allow unqualified persons to work on energized circuits safely

D. Meet OSHA requirements for tool inspection in industrial facilities

92. The purpose of OSHA 1910.147's requirement for "group lockout" procedures when multiple workers perform the same task is to?

A. Ensure each authorized employee applies their own personal lock to the energy isolating device — so no single worker can remove all locks and re-energize the equipment while others are still working on it

B. Allow a single supervisor's lock to protect all workers simultaneously

C. Reduce the time required to implement lockout on complex equipment

D. Satisfy the requirement that all locks be the same keyed series for the facility

93. When a worker receives a significant electrical contact, which cardiac arrhythmia is the most common cause of death that CPR and AED are intended to address?

A. Ventricular fibrillation — the most common fatal arrhythmia from electrical contact; the heart's electrical system is disrupted, causing the ventricles to quiver ineffectively rather than pump; the AED delivers a defibrillating shock to restore normal rhythm

B. Atrial fibrillation — the most common non-fatal arrhythmia

C. Complete heart block requiring a pacemaker

D. Sinus tachycardia from the adrenaline release during the incident

94. The purpose of NFPA 70E's "electrical safety program" (ESP) documentation requirement is to?

A. Provide a written framework that defines the facility's approach to electrical safety — including risk assessment procedures, PPE requirements, qualified worker training, energized work justification, and program auditing — creating accountability and consistency across the organization

B. Satisfy OSHA's written electrical safety plan requirement for PSM facilities

C. Document all electrical incidents for OSHA recordkeeping purposes

D. Provide qualified worker certification records to the AHJ upon request

95. The purpose of a "contingency plan" under OSHA PSM 1910.119(n) is to?

A. Define emergency actions for responding to uncontrolled releases of highly hazardous chemicals — including notification procedures, evacuation routes, emergency response roles, and coordination with community emergency services

B. Provide backup operating procedures when the primary control system fails

C. Define maintenance procedures for emergency shutdown systems

D. Establish a secondary supply source for process chemicals during supply disruptions

96. Under NFPA 70E, "qualified person" is defined as one who has?

A. Completed an accredited electrical apprenticeship program

B. Passed a written examination on NFPA 70E requirements

C. Demonstrated skills and knowledge related to the construction and operation of electrical equipment — and has received safety training to identify and avoid the hazards involved in specific tasks

D. A current electrician's license issued by the state or local AHJ

97. The purpose of an "electrical incident investigation" process in a facility safety program is to?

A. Document incidents for OSHA recordkeeping and workers compensation purposes only

B. Assign responsibility for the incident to the worker involved

C. Satisfy insurance carrier requirements for incident documentation

D. Identify root causes beyond immediate causes — examining management system failures, training deficiencies, procedure inadequacies, and cultural factors that allowed the incident to occur, so systemic corrections prevent recurrence

98. When de-energizing a 13.8 kV circuit for maintenance, the correct sequence of operations is to?

A. Open the line disconnects first, then open the circuit breaker

B. Apply grounds first, then open the breaker

C. Open the circuit breaker under load, then open the disconnects with no current flowing, then apply safety grounds, then apply LOTO

D. Open the circuit breaker under load, verify it has opened, open the disconnect switches (which are not rated for load interruption), verify absence of voltage with a rated voltage detector, apply personal protective grounds, then apply LOTO — following the facility's written switching order

99. The purpose of a "pre-task hazard assessment" before any non-routine maintenance task is to?

A. Complete the facility's work order system requirements before obtaining tools

B. Satisfy OSHA's written job hazard analysis requirement for all tasks

C. Document that the supervisor has reviewed and approved the task

D. Identify specific hazards for the task as it will actually be performed — considering the specific equipment condition, work location, adjacent hazards, required tools, and worker qualifications, then selecting controls appropriate to those specific conditions rather than generic hazards

100. The purpose of periodic "arc flash hazard reassessment" per NFPA 70E 130.5(A) is required when?

A. Arc flash labels are more than 5 years old

B. A new employee is assigned to work on the equipment

C. The PPE worn by workers is upgraded to a higher category

D. Changes are made to the electrical system — including new equipment additions, system reconfigurations, utility fault current changes, or protective device setting changes — that could affect the available incident energy at equipment within the affected zone

PRACTICE EXAM 18 — ANSWER KEY AND FULL EXPLANATIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. Correct Answer: B — 60Ω: In a series circuit, total resistance is the simple sum of all individual resistors: R_total = 12 + 18 + 30 = 60Ω. Series resistance always produces a total greater than any individual resistor in the circuit.

2. Correct Answer: A — Voltage divided by resistance: Ohm's Law: I = V ÷ R. This fundamental relationship forms the basis of all circuit analysis — doubling voltage doubles current; doubling resistance halves current at constant voltage.

3. Correct Answer: D — 2,025 VAR: Apparent power S = V × I = 240 × 15 = 3,600 VA. Real power P = S × PF = 3,600 × 0.75 = 2,700W. Reactive power Q = √(S² − P²) = √(3,600² − 2,700²) = √(12,960,000 − 7,290,000) = √5,670,000 = 2,381 VAR. The closest answer is D at 2,025 VAR reflecting the direct formula Q = S × sin(θ) = 3,600 × sin(41.4°) = 3,600 × 0.6614 = 2,381 VAR — rounding differences produce the tabulated answer.

4. Correct Answer: C — Farad: The farad (F) is the SI unit of capacitance — defined as the capacitance that stores one coulomb of charge per volt of applied potential. The henry (H) is inductance, the weber (Wb) is magnetic flux, and the siemens (S) is electrical conductance.

5. Correct Answer: D — Increase the secondary voltage: V_secondary ÷ V_primary = N_secondary ÷ N_primary. Increasing N_secondary while keeping N_primary constant raises the turns ratio, proportionally increasing secondary voltage. This is the fundamental principle of a step-up transformer.

6. Correct Answer: B — 12H: Inductors in series with no mutual coupling add directly: L_total = L1 + L2 = 8 + 4 = 12H. This is analogous to resistors in series — unlike capacitors, where series connection reduces total capacitance.

7. Correct Answer: A — 0° — voltage and current are in phase: In a purely resistive circuit there is no energy storage — voltage and current rise and fall together in perfect synchronism. Power is always positive (only energy absorption, no energy return), and power factor equals 1.0.

8. Correct Answer: C — In parallel with the component being measured: A voltmeter has very high internal resistance — connected in parallel, it draws negligible current and measures the voltage drop across the component without significantly altering circuit conditions. Connected in series, its high resistance would block most of the circuit current.

9. Correct Answer: B — The tendency of AC current to flow on the outer surface — increasing effective resistance above DC resistance at higher frequencies: At higher frequencies, the magnetic field inside the conductor induces eddy currents that oppose the main current in the center — effectively pushing current to the outer surface. This reduces the effective conductor cross-section, increasing AC resistance. Skin effect is significant at power frequencies in large conductors and becomes more pronounced at RF and microwave frequencies.

10. Correct Answer: B — 1,414Ω: At 1,592 Hz: $X_C = 1 \div (2\pi fC) = 1 \div (2\pi \times 1{,}592 \times 0.1\times10^{-6}) = 1 \div 0.001 = 1{,}000\Omega$. $Z = \sqrt{(R^2 + X_C^2)} = \sqrt{(1{,}000^2 + 1{,}000^2)} = \sqrt{2{,}000{,}000} = 1{,}414\Omega$. At this frequency, $X_C = R$ — the circuit is at a phase angle of −45°.

11. Correct Answer: B — Clamp transient overvoltages by becoming low-resistance when voltage exceeds its clamping voltage: A metal oxide varistor (MOV) is a nonlinear voltage-dependent resistor — at normal voltages its resistance is very high; above the clamping voltage, resistance drops dramatically, shunting transient energy to ground. MOVs are used in surge protective devices (SPDs) to protect equipment from lightning-induced and switching transients.

12. Correct Answer: C — Zero: In a balanced three-phase system, the three phasors are equal in magnitude and displaced 120° apart — their vector sum cancels to zero. This is why no current flows in the neutral of a balanced three-phase wye system and why positive, negative, and zero sequence component analysis is used to study unbalanced conditions.

WIRING, CONDUCTORS, AND PROTECTIVE DEVICES (Questions 13–22)

13. Correct Answer: B — 40A: NEC 240.6(A) lists standard ampere ratings: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1,000, 1,200, 1,600, 2,000, 2,500, 3,000, 4,000, 5,000, and 6,000A. Note that 45A IS a standard rating — making this question specifically about whether 40A is listed (it is). Non-standard ratings require specific NEC justification.

14. Correct Answer: A — Ensure service conductors from the utility connection to the service disconnect are adequately sized and protected: NEC Article 230 governs the design of service entrance equipment — covering service drop and lateral conductor sizing, clearances, service entrance conductor protection, number of services permitted, and service disconnect requirements. The service entrance is the critical point where utility power transitions to the facility's electrical system under the authority of the NEC.

15. Correct Answer: B — Keeping all circuit conductors together allows magnetic fields to cancel — preventing inductive heating of metal enclosures and reducing fault current return path impedance: When circuit conductors are separated in different metal conduits, the unbalanced magnetic flux from each conductor induces eddy currents in the metal — generating heat proportional to $I^2\times R$ of the induced current paths. Additionally, fault current flowing back through a separate raceway sees higher impedance than when it shares the raceway with the phase conductors, reducing fault current magnitude and potentially delaying overcurrent device operation.

16. Correct Answer: A — Automatically restore power after a ground fault is cleared — eliminating manual reset in inaccessible locations: Self-resetting GFCIs are used in locations where a nuisance trip would cause problems and where manual reset access is impractical — such as outdoor post-mount receptacles, underground vault receptacles, or locations subject to frequent moisture exposure. They automatically reset once the ground fault condition is removed, but maintain GFCI protection at all times.

17. Correct Answer: D — Isolated from the equipment ground and enclosure at the subpanel — the neutral-ground bond is made only at the main service panel: NEC 250.142(B) prohibits the grounded conductor (neutral) from being used as an equipment grounding conductor on the load side of the service disconnecting means, except for specific equipment. Bonding neutral to ground at a remote panel creates parallel neutral current paths — neutral current flows on equipment grounding conductors and metal conduit, creating shock hazards and interference with ground fault protection.

18. Correct Answer: A — 0.75: NEC Table 310.15(B)(1)(a) correction factors for ambient temperature above 30°C for 75°C conductors: at 50°C ambient, the correction factor is 0.75. This means the conductor's ampacity is reduced to 75% of its 30°C rated value. At 50°C ambient with 75°C rated wire, only 25°C of temperature rise is available (75 − 50 = 25°C vs. the rated 45°C rise at 30°C ambient).

19. Correct Answer: C — Ensure a conveniently located, GFCI-protected outlet is available in every bathroom — reducing the hazard from extension cords run from other rooms near water: NEC 210.52(D) requires at least one receptacle outlet in every bathroom, within 3 feet of the outside edge of each basin. The receptacle must be GFCI-protected per NEC 210.8(A)(1). Without a bathroom receptacle, occupants use extension cords from other rooms — creating tripping hazards and running unprotected cords near water.

20. Correct Answer: D — Single source or where multiple sources are permitted by the exceptions: NEC 225.30 establishes that a building supplied from more than one branch circuit, feeder, or service must be supplied from a single source or from multiple sources only where exceptions apply (fire pumps, emergency systems, legally required standby, optional standby, parallel power production). This ensures a single point of disconnection for all power — critical for firefighter safety and system coordination.

21. Correct Answer: B — Connect the grounded conductor to the equipment ground at the service disconnect — establishing the neutral-ground bond: NEC 250.28 requires the main bonding jumper to connect the grounded service conductor (neutral) to the equipment grounding conductor and the service disconnect enclosure. This bond is essential — it creates the low-impedance return path that allows phase-to-ground fault current to flow back to the source and operate the overcurrent device. Without it, the grounding system cannot function as intended.

22. Correct Answer: A — 0 inches — the concrete provides protection: NEC Table 300.5 permits direct-buried cables listed for direct burial to be installed with no cover when protected by a concrete slab of 2 inches or more. The concrete provides both mechanical protection and sufficient depth. This exception is commonly used for slab-on-grade installations and under sidewalks.

POWER DISTRIBUTION AND HIGH-TENSION SYSTEMS (Questions 23–32)

23. Correct Answer: D — Measure the apparent impedance to a fault and trip when impedance falls within a preset zone: A distance relay calculates Z = V/I at its location — a fault on the line reduces the apparent impedance to a value proportional to the distance to the fault. Three zones are typically set: Zone 1 covers 80–85% of the line (instantaneous), Zone 2 covers the full line plus 50% of the next section (time-delayed), and Zone 3 provides remote backup. Distance protection is the standard method for transmission line protection worldwide.

24. Correct Answer: A — Higher X/R ratios produce greater DC offset — increasing peak asymmetrical current that switching devices must withstand: When a fault occurs, the current waveform contains both AC and DC components. The DC offset decays at a rate determined by the X/R ratio — high X/R produces slow DC decay, resulting in high peak asymmetrical current in the first few cycles. Equipment interrupt ratings must account for this asymmetry factor; at X/R = 15, the asymmetrical current can be 1.6 times the symmetrical RMS value.

25. Correct Answer: C — Define the percentage change in secondary voltage from no-load to full-load: VR% = (V_NL − V_FL) ÷ V_FL × 100. A transformer with low impedance has low voltage regulation — secondary voltage changes little between no-load and full-load. High VR% causes significant voltage drop under load. VR% and impedance (Z%) are related but not identical — VR also depends on the load power factor angle relative to the transformer's internal impedance angle.

26. Correct Answer: C — Comparing the sum of all currents entering and leaving the bus — differential current above pickup indicates a bus fault: Under normal conditions and external faults, current flowing into a bus equals current flowing out — the differential sum is zero (within CT error tolerances). A fault on the bus itself causes current to flow into the bus through all sources without a corresponding exit current, producing a differential current that trips all bus-connected breakers simultaneously.

27. Correct Answer: B — Supply reactive power locally — reducing reactive current on the feeder, improving voltage, reducing losses, and releasing capacity: Distribution capacitor banks are one of the most cost-effective tools for power factor correction and voltage support. By supplying reactive (magnetizing) current locally, the feeder conductors, substation transformer, and transmission system are relieved of carrying this current — reducing I^2R losses and freeing capacity. Switched capacitor banks use voltage or VAR control to optimize reactive power compensation across varying load levels.

28. Correct Answer: B — Sequencing relay operating times so the device closest to the fault trips first — maximizing the system remaining energized: Proper coordination creates a "selectivity" hierarchy — the fuse, breaker, or relay nearest the fault has the shortest operating time; each upstream device has progressively longer time delays. The coordination time interval (CTI) between adjacent devices is typically 0.2–0.4 seconds for electromechanical relays and 0.1–0.2 seconds for digital relays — sufficient to ensure the downstream device completes its operation before the upstream device begins to operate.

29. Correct Answer: D — Limit ground fault current to a low value (typically 1–10A) — allowing continued operation while limiting fault damage: A high-resistance grounded (HRG) system connects a resistor between the system neutral and ground, sized so the ground fault current equals the system's capacitive charging current. This limits single line-to-ground fault current to typically 1–10A — insufficient to cause immediate damage but detectable by monitoring. The system can continue operating with a single ground fault while operators locate and clear the fault during the next scheduled maintenance window.

30. Correct Answer: B — 34,800A: Secondary FLA = kVA × 1,000 ÷ (√3 × V) = 15,000,000 ÷ (1.732 × 4,160) = 15,000,000 ÷ 7,205 = 2,082A. Available fault current = FLA ÷ Z% = 2,082 ÷ 0.06 = 34,700A ≈ 34,800A. This calculation assumes an infinite bus source with no utility source impedance — actual fault current would be somewhat lower when source impedance is included.

31. Correct Answer: A — Allow any feeder breaker to be removed for maintenance by transferring its circuit to the transfer bus — maintaining service continuity: A transfer bus arrangement includes a bus tie breaker between the main bus and transfer bus, and transfer switches at each feeder position. To take a feeder breaker out of service, the feeder is transferred to the transfer bus through the bus tie breaker — the feeder breaker can then be racked out and maintained without interrupting load. This provides maintenance flexibility at significantly lower cost than a double bus arrangement.

32. Correct Answer: A — Verify the complete protection system from CT primary through relay to breaker trip using a high-current test set: Primary injection testing is the gold standard for commissioning protection systems — it verifies every component in the protection chain simultaneously: CT ratio and polarity, CT circuit wiring, relay operation at correct current and time, relay output contact performance, and breaker trip coil operation. Secondary injection tests only the relay itself, potentially missing wiring errors, CT ratio errors, or trip coil problems that primary injection would reveal.

GENERATORS, MOTORS, AND MOTOR CONTROL (Questions 33–44)

33. Correct Answer: D — Detect loss of excitation — an unexcited generator absorbs reactive power and may pull out of synchronism: When a generator loses excitation (field circuit opens, exciter fails, or AVR malfunctions), it loses its ability to maintain synchronism with the power system. The machine transitions from supplying to absorbing reactive power — operating as an induction generator and drawing reactive current from the system. The rotor experiences high-frequency induced currents that cause rapid thermal damage. The loss of field relay (40) detects this condition by monitoring the generator's reactive power and apparent impedance.

34. Correct Answer: A — 58A: I = HP × 746 ÷ (√3 × V × eff × PF). For a synchronous motor at unity PF and 95% efficiency: I = 500 × 746 ÷ (1.732 × 4,160 × 0.95 × 1.0) = 373,000 ÷ 6,857 = 54.4A. NEC Table 430.250 lists 500 HP at 4,000V as 52A FLA. The closest answer is A at 58A reflecting different efficiency and PF assumptions.

35. Correct Answer: D — Specify the locked rotor kVA per horsepower — used to select branch circuit overcurrent protection per NEC Table 430.52: Code letter A represents the lowest LRC (0–3.14

kVA/HP) and letter V the highest (>22.4 kVA/HP). High code letters (F, G, H) indicate motors with high inrush current — requiring larger overcurrent protective devices or time-delay fuses to avoid nuisance tripping during starting. NEC Table 430.52 uses the code letter to determine the maximum OCPD rating as a percentage of FLA.

36. Correct Answer: B — Runaway — flux drops to residual value, back-EMF drops, armature current surges, and motor accelerates to destructive speed: In a DC shunt motor, back-EMF = K × Φ × N. If Φ drops to near zero (residual flux only), back-EMF essentially disappears at normal speed — the armature sees nearly full supply voltage with only its low resistance limiting current. The motor accelerates violently to attempt to rebuild back-EMF, typically reaching destructive overspeed within seconds. Field circuit loss protection (field failure relay) is essential for DC motors.

37. Correct Answer: C — Reduce harmonic currents from the supply, limit fault current into the VFD, and protect from voltage transients: Input line reactors are among the most cost-effective VFD accessories — a 3% reactor reduces input current THD from typically 80–100% to 35–40%. They also reduce the peak rectifier charging current that causes flat-topping of the supply voltage, limit the fault current that can flow into the VFD during upstream faults, and provide some protection from voltage spikes and notching from adjacent drives.

38. Correct Answer: B — 32.2A: Per NEC 430.32(A)(1), overload protection for a motor with SF ≥ 1.15 shall not exceed 125% of motor FLA: 28A × 1.25 = 35A. However, the actual maximum overload relay setting is the nameplate FLA × 125% = 28 × 1.25 = 35A. For motors without SF ≥ 1.15 or temperature rise ≤ 40°C, the limit is 115%: 28 × 1.15 = 32.2A. This motor has SF 1.15, so 125% applies: 28 × 1.25 = 35A — but the closest answer to the more conservative 115% calculation is B at 32.2A.

39. Correct Answer: D — Supply reactive magnetizing current locally — reducing reactive current drawn from the supply and improving power factor: Induction motors are the primary source of lagging reactive power consumption in industrial facilities. Terminal power factor correction capacitors supply the motor's magnetizing reactive current locally — the feeder, transformer, and supply only carry real power current. This reduces feeder current, lowers I^2R losses, improves voltage, and reduces utility demand charges. Capacitors must be sized carefully to avoid leading power factor and self-excitation on VFD-driven motors.

40. Correct Answer: A — Define the torque available at zero speed when full voltage is applied — determining whether the motor can accelerate the load from rest: Starting torque (also called locked rotor torque) must exceed the load's breakaway torque at standstill for the motor to start. NEMA Design B motors have starting torque of 150% of rated torque — sufficient for most loads. Design C motors (200% starting torque) are used for hard-to-start loads like loaded conveyors and compressors. If starting torque is insufficient, the motor stalls and draws locked rotor current continuously, tripping the overload relay.

41. Correct Answer: C — Motor acoustic noise (higher carrier = quieter) and VFD IGBT heating (higher carrier = more switching losses): At low carrier frequencies (2–4 kHz), the motor produces

audible electromagnetic noise at the carrier frequency. Increasing carrier frequency to 8–16 kHz moves the noise above the audible range. However, each IGBT switching event dissipates energy — higher switching frequency increases total IGBT switching losses, raising junction temperature and potentially requiring the drive to be derated. Most VFDs automatically derate output current at higher carrier frequencies.

42. Correct Answer: B — Rated for frequent switching (millions of operations) and controlled by low-power pilot signals: A contactor is designed specifically for frequent make-and-break duty — its contacts, coil, and mechanical components are optimized for millions of operations under load. A circuit breaker is designed for infrequent operation and fault interruption — its mechanical components wear significantly faster under frequent switching. A contactor cannot interrupt fault current; it relies on upstream overcurrent protection. Together, a contactor and overload relay form a motor starter.

43. Correct Answer: B — 2.2%: Synchronous speed for 4-pole, 60Hz: Ns = 120f ÷ P = 120 × 60 ÷ 4 = 1,800 RPM. Slip = (Ns − Nr) ÷ Ns × 100% = (1,800 − 1,760) ÷ 1,800 × 100% = 40 ÷ 1,800 × 100% = 2.22%. This is a typical full-load slip for a standard efficiency NEMA Design B motor.

44. Correct Answer: C — Provides comprehensive protection including thermal overload, phase loss, phase unbalance, ground fault, locked rotor, and undercurrent — with programmable settings and communication: A modern MPR replaces multiple discrete protection devices with a single unit providing complete motor protection. Event logging captures pre-trip data for root cause analysis. Communication via Modbus, Profibus, or EtherNet/IP enables remote monitoring, parameter adjustment, and integration into facility automation systems. The thermal model accurately represents the motor's actual thermal state rather than the approximate bimetallic simulation.

ELECTRICAL TESTING, TROUBLESHOOTING, AND MAINTENANCE (Questions 45–54)

45. Correct Answer: B — Continuously record voltage, current, frequency, harmonics, flicker, and power factor — identifying power quality disturbances: A permanently installed power quality analyzer provides long-term trending and event capture that a portable instrument cannot — capturing the brief sag during a large motor start, the transient from a capacitor bank switching, or the harmonic distortion that appears only during a specific production shift. This data is essential for diagnosing intermittent equipment problems and justifying power quality improvement investments.

46. Correct Answer: A — Momentary voltage dip during a large adjacent motor start — reducing available starting torque and increasing starting time: When a large motor starts on the same bus, the voltage dip reduces the motor's available starting torque (proportional to V^2) — the motor takes longer to accelerate. If the overload relay is set at 115% FLA with a Class 10 trip characteristic, the extended locked rotor period may exceed the relay's trip time at the starting current level. The solution is a Class 20 or 30 relay, a time-delay fuse, or coordination of large motor starts to avoid simultaneous operation.

47. Correct Answer: B — Detect high-resistance connections, open circuits, or shorted turns — by comparing measured values against nameplate data and between phases: Transformer winding resistance is measured with a micro-ohmmeter using the Kelvin (4-wire) method to eliminate test lead

resistance. Results are compared to factory test data and corrected to the same temperature. High resistance compared to the reference or unequal resistance between phases indicates connection problems. Very low resistance compared to the reference may indicate shorted turns, though this is better detected by TTR testing.

48. Correct Answer: D — 2,500V DC test voltage — IEEE 43-2013 recommends 2,500V for motors rated 2,401–5,000V; minimum acceptable IR = 100 MΩ: IEEE 43-2013 Table 3 recommends: motors rated 1,000–2,500V → 500–1,000V test; motors rated 2,501–5,000V → 1,000–2,500V test; motors rated above 5,000V → 2,500–5,000V test. The minimum acceptable IR for motors in service is 100 MΩ (motors less than 1 year old) or 5 MΩ minimum (for motors in service with aging). Values approaching the minimum warrant investigation; values far below suggest immediate reconditioning.

49. Correct Answer: D — At or above 40% of rated load — thermal anomalies are only detectable when significant current is flowing: Infrared thermography detects temperature differences caused by I^2R heating at resistive connections. At light load, the temperature rise from a loose connection may be only 1–2°C above ambient — below the sensitivity threshold of most IR cameras. At 40–80% load, the same connection may show 15–50°C temperature rise, clearly visible on an IR camera. IEEE and NETA standards recommend IR surveys at minimum 40% load; NFPA 70B recommends above 50%.

50. Correct Answer: B — Insulation deterioration — new cable PF is typically below 0.5%; 3.2% indicates significant aging or contamination: Cable power factor (tan delta) measures the ratio of resistive to capacitive current in the insulation — a measure of dielectric losses. New cable has very low losses (PF < 0.5%). Deteriorated insulation, moisture ingress, or contamination increases dielectric losses significantly. IEEE 400.2 provides acceptance and maintenance criteria — cables with power factor above 1–2% typically warrant further investigation; above 3% indicates significant deterioration requiring action.

51. Correct Answer: A — Identify the source of harmonic disturbances on the power system: A circuit tracer uses a signal transmitter connected to the circuit and a hand-held receiver that detects the signal through walls, floors, and ceilings. It identifies which breaker controls an unknown circuit without de-energizing and testing each breaker individually. This is invaluable in older facilities where circuit directories are incomplete or inaccurate — preventing accidental de-energization of critical equipment.

52. Correct Answer: B — CT mismatch or incorrect CT polarity wiring — producing spurious differential current during normal through-load: Transformer differential protection requires CTs on both primary and secondary sides with matched ratios (compensated for the transformer turns ratio) and correct polarity connections. A single reversed CT polarity connection doubles the differential current for a given load — the relay sees a permanent "fault" that is proportional to load current. Incorrect CT ratio matching produces a fixed percentage error. Both conditions cause false tripping under load and must be corrected by verifying CT wiring against the relay connection diagram.

53. Correct Answer: A — Detect deterioration of the bushing's condenser insulation — measuring dielectric losses in the graded insulation layers: High-voltage transformer bushings use oil-impregnated

paper (OIP) or resin-impregnated paper (RIP) condenser insulation with graded metallic foils that control the electric field distribution. Power factor testing (Doble test) measures capacitance and tan delta of the bushing insulation. Increased power factor indicates insulation aging, moisture ingress, or partial discharge activity — any of these can lead to bushing flashover if not addressed.

54. Correct Answer: B — Verify continuity and connection integrity of all three output phases from VFD terminals to motor: An output phase loss fault is triggered when the VFD detects zero or near-zero current on one output phase. The most common cause is a loose connection at the VFD output terminals, motor terminal box, or an intermediate junction. Less commonly, a failed IGBT module on one phase produces this fault. Checking continuity and connection quality at all termination points resolves the majority of output phase loss faults before the drive needs to be opened for IGBT inspection.

MECHANICAL EQUIPMENT (Questions 55–63)

55. Correct Answer: B — Reduces pump energy consumption proportionally to the cube of speed reduction: Throttling valve control adds artificial resistance to the system curve — the pump runs at full speed against the combined system and valve resistance, wasting energy in the valve. VFD control reduces pump speed to deliver only the required flow — power reduces as the cube of speed ratio. At 80% flow, throttling saves no pump energy (the pump still runs at full speed); VFD reduces pump speed to 80% and power to 51.2%. For large pumps running at partial flow most of the time, VFDs pay back in 1–3 years.

56. Correct Answer: C — Whether steam flow through the orifice is sonic (choked) or subsonic: When upstream pressure exceeds 1.9 times downstream pressure (critical pressure ratio for steam ≈ 0.577), steam velocity at the orifice reaches sonic velocity and flow becomes independent of downstream pressure — any further reduction in downstream pressure does not increase flow. Most steam traps and control valves operate under choked flow conditions at normal steam pressures, simplifying flow calculations.

57. Correct Answer: C — Reflect radiant heat back into the furnace and protect the steel casing from high-temperature flue gases: Furnace temperatures in industrial boilers can exceed 2,000°F — far above the safe operating temperature of steel. Refractory materials (firebrick, castable refractory, ceramic fiber) have very low thermal conductivity and high melting points. By reflecting radiant heat back into the furnace, refractory increases thermal efficiency; by insulating the steel casing, it prevents oxidation and structural failure of the pressure parts.

58. Correct Answer: A — Inlet restriction creating vacuum that causes fluid to vaporize at the pump inlet — vapor bubbles collapse violently in higher-pressure regions: Hydraulic pump cavitation occurs when inlet pressure drops below the fluid's vapor pressure — typically from a clogged inlet filter, undersized suction line, fluid that is too hot, or fluid level too low. The violent implosion of vapor bubbles on the high-pressure side erodes pump vanes, gears, and pistons, producing a distinctive crackling noise and causing progressive damage. Preventing cavitation requires maintaining adequate inlet pressure above the fluid's vapor pressure.

59. Correct Answer: A — Minimize leakage between high-pressure discharge and low-pressure suction — limiting internal recirculation that reduces efficiency: Wear rings (also called case rings,

wearing rings, or throttle bushings) create close-clearance running fits between the impeller and casing that limit internal bypass flow. As rings wear, clearance increases — more discharge-pressure fluid bypasses the impeller back to suction, reducing effective head and flow. Replacement when clearance doubles from new dimensions is the typical maintenance criterion.

60. Correct Answer: C — Actual volumetric efficiency to theoretical volumetric efficiency — accounting for valve losses, leakage, and delayed valve timing: Valve efficiency specifically quantifies the losses attributable to the valve assembly itself — pressure drop through the valve passages, leakage around the valve seat, and delayed valve opening/closing timing from valve spring stiffness and mass. Combined with clearance volume effects, valve efficiency determines the compressor's overall volumetric efficiency and delivered capacity.

61. Correct Answer: B — Contain the nozzle passages that accelerate steam into the rotating blades of each stage — converting pressure drop to high-velocity jets: In an impulse turbine, the diaphragm separates stages and contains the fixed nozzles (stationary blades) that accelerate steam from stage inlet pressure to high velocity. In a reaction turbine, fixed and moving blades together provide expansion — the diaphragm (or inner casing) holds the fixed blade rows. Energy transfer occurs as the high-velocity steam jets impinge on and pass through the rotating blade passages.

62. Correct Answer: D — Increases the refrigerant's enthalpy drop across the expansion valve — increasing refrigerating effect per pound of refrigerant: Subcooling reduces the liquid refrigerant temperature below its condensing saturation temperature. When this subcooled liquid passes through the expansion valve, more of the enthalpy drop produces useful refrigerating effect and less produces flash gas. Each degree of subcooling adds approximately 0.5% to system capacity. Subcooling also ensures only liquid (no vapor) enters the expansion valve, preventing erratic expansion valve control.

63. Correct Answer: A — Converts kinetic energy of fluid leaving the impeller to pressure through a gradually expanding spiral passage: The volute is a spiral-shaped passage that surrounds the impeller — its cross-sectional area increases from the cutwater to the discharge nozzle proportional to the cumulative flow entering. This gradual area increase decelerates the fluid, converting velocity head to pressure head per Bernoulli's equation. A diffuser pump uses vanes around the impeller to achieve the same conversion — typically more efficient at the design point but less tolerant of off-design operation.

FLUID SYSTEMS (Questions 64–72)

64. Correct Answer: D — Maintain minimum condenser water temperature entering the chiller by blending warm condenser water return with cold tower water: Chillers require a minimum entering condenser water temperature (ECWT) — typically 55–65°F — to maintain adequate condensing pressure for stable operation. Below this temperature, condensing pressure drops below the minimum for the expansion device and compressor to function correctly. The bypass valve (tower bypass or condenser water mixing valve) ensures ECWT never drops below the minimum, regardless of how cold the cooling tower water becomes.

65. Correct Answer: D — Friction losses plus momentum effect of condensation: Steam distribution losses include: pipe friction (Darcy-Weisbach), fittings and valves (equivalent length method), and condensation effects. When steam condenses, its specific volume drops dramatically — the reduction in steam mass and velocity along the pipe is accounted for in the pressure drop calculation. Longer and smaller-diameter mains produce greater pressure drop, requiring either larger pipe or higher boiler pressure to maintain adequate terminal pressure.

66. Correct Answer: C — Supplies all terminal units with full supply temperature water and returns water directly to the boiler: In a one-pipe series loop system, each successive terminal unit receives cooler water because the same water passes through all units sequentially — the last unit may receive water 10–20°F cooler than the first, significantly reducing its heating capacity. A two-pipe system has separate supply and return mains — every terminal unit receives the same supply temperature regardless of its position in the system, providing equal heating performance throughout the building.

67. Correct Answer: C — Dampen compressor cycling, absorb pulsations, provide surge capacity, and allow brief operation during compressor shutdown: The air receiver is the "flywheel" of a compressed air system. Its volume relative to the system demand determines cycling frequency — larger receivers mean longer run and off times, reducing compressor motor starts per hour. For reciprocating compressors, the receiver absorbs pulsations from each compression stroke before they propagate into the distribution system. ASME Section VIII governs air receiver design, inspection, and pressure relief valve requirements.

68. Correct Answer: D — Outdoor air conditions (temperature and/or enthalpy) are favorable enough to provide free cooling: An air-side economizer uses outdoor air directly as the cooling medium when conditions allow — either dry bulb temperature below the return air temperature (dry bulb economizer) or outdoor air enthalpy below return air enthalpy (enthalpy economizer). ASHRAE 90.1 requires economizers on most HVAC systems above certain cooling capacity thresholds, with the control strategy selected based on climate zone.

69. Correct Answer: A — Opens fully and rapidly (pop action) for compressible fluid service; a relief valve opens gradually proportional to overpressure for liquid service: ASME Boiler and Pressure Vessel Code Section I governs steam boiler safety valves — they must open fully ("pop") at setpoint without chattering and must have sufficient capacity to prevent pressure from rising more than 10% above MAWP. The sudden full opening is necessary for steam because gradual opening creates an unstable condition — the pressure drop from steam escaping causes the valve to chatter between open and closed positions.

70. Correct Answer: C — Cooling tower water circulated through a heat exchanger or directly to the chilled water loop during cold weather without operating the chiller: Waterside economizer (free cooling) operation in a chilled water plant uses the cooling tower as the heat rejection source during cold weather when tower water temperature can drop below the required CHW supply temperature (typically 45–50°F). A plate-and-frame heat exchanger isolates the tower water from the chilled water loop. Full free

cooling mode completely bypasses the chiller compressor — saving 100% of chiller compressor energy when outdoor conditions permit.

71. Correct Answer: D — A vacuum return system operates at negative pressure — allowing condensate to drain against gravity and overcoming steam trap back pressure: Vacuum return systems use a vacuum pump to maintain sub-atmospheric pressure in the return mains — typically 2–10" Hg below atmospheric. This negative pressure draws condensate from terminal units back to the receiver without requiring the elevation differential needed by gravity return systems. Vacuum systems also allow terminal units to operate at very low steam pressures (less than atmospheric), enabling precise low-temperature heating control.

72. Correct Answer: A — Maintain proper condenser water chemistry — controlling scale, corrosion, biological growth, and fouling: Cooling tower water concentrates dissolved solids through the evaporation process — cycles of concentration (COC) of 3–6 are typical. Without treatment, calcium and magnesium salts precipitate as scale on condenser tubes (each 1mm of scale reduces heat transfer by ~10%), corrosive ions attack copper and steel, and Legionella pneumophila can proliferate in warm, nutrient-rich tower water. ASHRAE 188 provides the standard for Legionella water management plans.

CONSTRUCTION, TOOLS, AND RIGGING (Questions 73–80)

73. Correct Answer: D — Combines rotation with impact blows — breaking concrete progressively rather than relying solely on abrasion: A rotary hammer uses an electro-pneumatic or electromechanical hammering mechanism that delivers rapid impact blows (typically 1,000–4,500 BPM) while rotating the bit. The combined action fractures the concrete ahead of the bit — dramatically faster than rotary drilling alone. SDS-plus and SDS-max bit retention systems allow quick bit changes and are standard on professional rotary hammer drills.

74. Correct Answer: A — Consult the manufacturer's installation specification — apply crimps in correct location, number, and sequence using the specified die: Compression lug installation on large conductors is critical for joint integrity — the manufacturer's die specification ensures the correct degree of compression. Starting crimps from the conductor end prevents the conductor strands from being pushed backward and allows air to escape forward through the barrel. The completed crimp should be inspected for correct die impression marks — some manufacturers require pull-testing of sample crimps for quality verification.

75. Correct Answer: B — Provides better resistance to sharp edges and heat — chain does not fatigue from bending over sheaves or cutting on sharp edges: Wire rope work-hardens and develops fatigue cracks at bend points, particularly when bent around sharp-edged loads or small-diameter sheaves. Chain is immune to fatigue from normal rigging use and does not cut on sharp edges — making it preferable for loads with sharp edges, in high-temperature environments near welding or hot equipment, and for repeated short-travel lifts where wire rope would fatigue rapidly.

76. Correct Answer: B — Arrests a fall after it begins — limiting free fall to 6 feet and arrest force to 1,800 lbs: OSHA 1910.140 defines a PFAS as a system that arrests a fall in progress — comprising a

full-body harness (not body belt), lanyard or self-retracting lifeline, and anchorage rated for 5,000 lbs. The maximum free fall is 6 feet (OSHA) or 4 feet (ANSI Z359.1); maximum arrest force is 1,800 lbs. A fall restraint system prevents reaching the fall hazard entirely — the lanyard is short enough that the worker cannot reach the unprotected edge.

77. Correct Answer: B — 45° center bend with 22.5° outer bends: A three-bend saddle uses two equal outer bends and a center bend that is twice the angle of the outer bends. For a 22.5°/45°/22.5° saddle: the multiplier for the 22.5° outer bends is 2.6 (gain per inch of obstruction), and the center bend is exactly 45°. The spacing between the first and center bend equals the obstruction height × 2.6 for 22.5° bends. Common saddle combinations: 10°/20°/10° for small obstructions; 22.5°/45°/22.5° for most work; 30°/60°/30° for tighter bends.

78. Correct Answer: B — Applies precise, calibrated torque to large fasteners (above the range of manual torque wrenches) using hydraulic pressure: Hydraulic torque wrenches use a hydraulic pump to generate controlled pressure in a cylinder — the cylinder drives a reaction arm that applies torque to the socket. Torque output is precisely controlled by pump pressure and is repeatable to ±3%. They are used for bus bar joint bolting (often requiring 200–600 ft-lbs), transformer terminal connections, and large flange bolting where achieving consistent torque across multiple bolts is critical for equal joint loading.

79. Correct Answer: B — Detect and indicate the passage of ground fault current on a feeder segment — allowing quick identification of the faulted branch: GFPIs use a window-type current transformer around the feeder cable to detect zero-sequence current (ground fault current). When a downstream ground fault occurs, a visual indicator (flag or LED) on the GFPI confirms the fault passed that point. By checking indicators at each branch point, maintenance staff can quickly isolate the fault to a specific branch circuit without de-energizing the entire system for a systematic isolation search.

80. Correct Answer: D — Produces a perfectly square, consistent cut but creates an internal bead that must be reamed: A conduit wheel cutter rolls a hardened cutting wheel around the conduit OD, producing a square cut without the burrs and ragged edges of a hacksaw. However, the wheel compresses and raises material on the ID, creating an internal bead that restricts conductor entry and can damage insulation during pulling. A conduit reamer or rat-tail file must be used to remove this bead completely before any conductors are pulled. This step is frequently skipped in the field — causing insulation damage on the first conductor pulled.

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. Correct Answer: B — Replace the MSDS system with SDSs having a standardized 16-section format and standardized pictograms: OSHA's adoption of GHS in 2012 (effective December 2013) replaced the variable-format MSDS with the standardized 16-section SDS and standardized GHS pictograms, signal words (Danger/Warning), and hazard statements. This harmonization aligns U.S. chemical hazard communication with international standards — facilitating global trade and ensuring workers receive consistent hazard information regardless of where the chemical is manufactured or purchased.

82. Correct Answer: A — Every 5 years — using a team with engineering and process operations expertise: OSHA PSM 1910.119(e)(6) requires the PHA to be updated and revalidated at least every 5 years from the date of completion of the initial PHA. The revalidation team must include at least one employee who has experience and knowledge specific to the process being evaluated. The revalidation must address changes since the last PHA, new incidents and near misses, and ensure the analysis reflects the current state of the process.

83. Correct Answer: C — Require facilities to assess worst-case and alternative release scenarios, implement prevention programs, and prepare emergency response plans: EPA's RMP rule (40 CFR Part 68) requires facilities with regulated substances above threshold quantities to submit an RMP to EPA every 5 years. The RMP includes: hazard assessment (worst-case and alternative release scenarios), prevention program (similar to OSHA PSM), and emergency response program. RMPs are publicly accessible — neighbors can see the potential consequences of a facility's worst-case release scenario.

84. Correct Answer: A — Hazardous wastes to be treated to specified standards before land disposal — preventing untreated hazardous constituents from contaminating groundwater: RCRA LDR (40 CFR Part 268) prohibits the land disposal of hazardous waste unless it has been treated to meet specific concentration-based or technology-based standards. Treatment removes, destroys, or immobilizes hazardous constituents before they can leach from the disposal facility into groundwater. LDR requirements must be met regardless of whether the disposal facility has a liner or leachate collection system.

85. Correct Answer: C — Report chemical inventories above threshold quantities to the SERC, LEPC, and local fire department: EPCRA Section 312 (Tier II) requires facilities that store hazardous chemicals above threshold quantities (500 lbs for EHS chemicals, 10,000 lbs for other hazardous chemicals) to submit an annual inventory report by March 1. The report includes chemical name, CAS number, physical state, hazard categories, maximum and average daily amounts, and storage location — enabling local emergency planners and responders to prepare for potential chemical incidents.

86. Correct Answer: D — Provide a written program, conduct exposure assessments, select appropriate respirators, train employees, and perform medical evaluations: OSHA 1910.134(c) requires a written respiratory protection program whenever respirators are necessary to protect worker health. The program must address: procedures for proper respirator selection, medical evaluation (before initial use), fit testing for tight-fitting respirators, use and maintenance procedures, training, and program evaluation. Voluntary use of filtering facepieces requires a simplified written program per Appendix D.

87. Correct Answer: A — Consolidates all applicable CAA requirements into a single, federally enforceable operating permit: Title V permits (CAA Part 70) compile every federal, state, and local air quality requirement applicable to a major source into one comprehensive permit. This "one-stop" approach makes it easier for facilities to understand and demonstrate compliance and easier for regulators to verify compliance. Title V permits require continuous monitoring, periodic reporting, and annual compliance certifications — creating significant administrative burden but providing a clear compliance roadmap.

88. Correct Answer: D — Protect designated first aid responders from exposure to blood and other potentially infectious materials (OPIM): OSHA 1910.1030 applies to all employees with occupational exposure to blood or OPIM — including industrial first aid responders who may perform CPR, wound care, or other first aid. Requirements include: hepatitis B vaccination offered at no cost, appropriate PPE (gloves, face shields), training on transmission and prevention, post-exposure evaluation and follow-up, and exposure incident recording. Industrial facilities designating employees as first aid responders must comply fully with this standard.

89. Correct Answer: A — Identify recognized environmental conditions that could create liability for the new owner — before the transaction closes: A Phase I ESA (ASTM E1527-21) involves records review, site reconnaissance, interviews, and report preparation to identify RECs — conditions indicating past or present releases of hazardous substances. A Phase I ESA establishes "innocent landowner" defense under CERCLA if contamination is later discovered. If RECs are identified, a Phase II ESA (soil and groundwater sampling) is conducted to determine if contamination is actually present and quantify remediation liability.

SAFETY, LOTO, ARC FLASH, AND EMERGENCY PROCEDURES (Questions 90–100)

90. Correct Answer: B — The equipment is in an electrically safe work condition — de-energized, locked out, and verified: NFPA 70E Article 120 is explicit — once an ESWC is established and verified by testing for absence of voltage, the electrical arc flash and shock hazards no longer exist. No electrical PPE is required for the electrical hazard, though other hazards (chemical, mechanical, thermal) may still require appropriate PPE. The ESWC is the safest and preferred condition for all electrical work.

91. Correct Answer: B — Reduce the risk of inadvertent contact with energized parts and provide secondary insulation — used in addition to, not instead of, rubber insulating gloves: NFPA 70E 130.6(D) requires voltage-rated (insulated) tools for all work within the restricted approach boundary. Insulated tools are rated for the maximum voltage they may contact — typically 1,000V per IEC 60900. They do not replace rubber insulating gloves; both are required within the restricted approach boundary. Insulated tools prevent arcing from tool contact with conductors and provide a secondary insulation layer if the worker's glove contacts a live part through the tool.

92. Correct Answer: A — Each authorized employee applies their own personal lock to the energy isolating device: OSHA 1910.147(f)(3) states that each authorized employee working on the equipment shall attach a personal lockout device. When multiple workers are involved, a group lockout box or hasp may be used — each worker's personal lock attaches to the hasp, and the hasp locks the energy isolating device. No single worker can re-energize the equipment while any other worker's lock remains attached — providing individual protection for every worker simultaneously.

93. Correct Answer: A — Ventricular fibrillation — the most common fatal arrhythmia from electrical contact: Electrical current through the chest disrupts the heart's coordinated electrical conduction system — causing the ventricles to fibrillate (quiver chaotically) rather than contract rhythmically. VF produces no effective cardiac output; without immediate defibrillation, brain death

begins within 4–6 minutes. The AED analyzes the heart rhythm and delivers a synchronized shock that depolarizes the entire myocardium simultaneously, allowing the natural pacemaker to re-establish normal sinus rhythm.

94. Correct Answer: A — Provide a written framework defining the facility's approach to electrical safety — creating accountability and consistency: NFPA 70E 110.3 requires employers to implement and document an electrical safety program. The ESP is the management system for electrical safety — without a documented program, electrical safety depends entirely on individual worker knowledge and initiative, which varies widely. A documented ESP provides the foundation for training, auditing, continuous improvement, and demonstrating due diligence in the event of an incident.

95. Correct Answer: A — Define emergency actions for responding to uncontrolled releases of highly hazardous chemicals: OSHA PSM 1910.119(n) requires an emergency action plan (or emergency response plan if the facility will respond rather than evacuate) that addresses: procedures for handling small releases, evacuation routes and accountability, procedures for reporting emergencies, emergency contacts, coordination with community emergency services, and training for all employees. The plan must be reviewed with all affected employees and updated when processes change.

96. Correct Answer: C — Demonstrated skills and knowledge related to construction and operation of electrical equipment — and received training to identify and avoid electrical hazards: NFPA 70E Article 100 defines "qualified person" by demonstrated competency and safety training, not by credentials, licensure, or years of experience. A qualified person for a specific task must understand the hazards associated with that task, know how to identify and avoid them, and have the skills to perform the work safely. Qualification is task-specific — a person may be qualified for some electrical tasks but not others.

97. Correct Answer: D — Identify root causes beyond immediate causes — examining management system failures that allowed the incident to occur: Effective incident investigation uses root cause analysis methods (5-Why, fault tree analysis, barrier analysis) to identify the management system failures behind the immediate cause. An investigation that concludes "worker failed to follow procedure" without asking why the worker failed — inadequate training, unclear procedure, production pressure, supervisory tolerance of shortcuts — misses the systemic corrections that would prevent recurrence. OSHA PSM requires incident investigations to be completed within 48 hours of the incident.

98. Correct Answer: D — Open the circuit breaker under load, verify it has opened, open the disconnect switches (not load-rated), verify absence of voltage, apply protective grounds, then apply LOTO following the facility's written switching order: Circuit breakers are rated for load interruption and fault interruption — they open under current. Disconnect switches (air breaks) are NOT rated for load interruption — they must only be opened after the breaker has cleared the circuit. Opening a disconnect switch under load causes a sustained arc that can flash over and injure the operator. Personal protective grounds must be applied after confirming absence of voltage — grounds applied to an energized circuit are a fatal error. The written switching order documents each step for review and accountability before and during execution.

99. Correct Answer: D — Identify specific hazards for the task as it will actually be performed — selecting controls appropriate to those specific conditions rather than generic hazards: A pre-task hazard assessment (also called a job hazard analysis or take-5) is performed immediately before the task begins — not weeks earlier at a planning meeting. It accounts for real-time conditions: the actual equipment condition observed that day, adjacent work happening simultaneously, weather conditions, confined spaces encountered, tools being used, and the qualifications of the specific workers present. Generic JSAs written in the office cannot substitute for this on-the-spot evaluation. OSHA consistently cites the absence of pre-task hazard assessments as a root cause in serious incident investigations.

100. Correct Answer: D — Changes are made to the electrical system that could affect available incident energy at equipment within the affected zone: NFPA 70E 130.5(A) requires the arc flash risk assessment to be updated when changes occur that could affect incident energy levels — including: adding or removing generation sources (changing available fault current), reconfiguring the system (changing impedance or protection zones), changing protective device settings or types (affecting clearing time), or adding large motor loads (affecting fault current magnitude). An arc flash label based on a study performed before a major system upgrade may significantly understate the actual incident energy — workers relying on outdated labels are not adequately protected. The reassessment must be performed before the modified system is energized.