

# PRACTICE EXAM 17: STATIONARY ENGINEER (ELECTRIC) SIMULATION — 100 QUESTIONS

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## ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. A 480V single-phase circuit feeds a load of 12 kW at 0.8 PF lagging. The line current is?

- A. 25A
- B. 31.25A
- C. 20A
- D. 40A

2. The opposition to current flow in an AC circuit caused by inductance is called?

- A. Resistance
- B. Impedance
- C. Capacitive reactance
- D. Inductive reactance

3. Three  $9\Omega$  resistors connected in parallel have an equivalent resistance of?

- A.  $27\Omega$
- B.  $9\Omega$

C.  $6\Omega$

D.  $3\Omega$

4. The energy stored in an inductor carrying 5A with an inductance of 2H is?

A. 10J

B. 50J

C. 25J

D. 5J

5. In a purely capacitive AC circuit, current?

A. Lags voltage by  $90^\circ$

B. Leads voltage by  $90^\circ$

C. Is in phase with voltage

D. Lags voltage by  $45^\circ$

6. The RMS value of a sinusoidal current with a peak value of 14.14A is approximately?

A. 14.14A

B. 20A

C. 7.07A

D. 10A

7. A wattmeter reads 8 kW and a VAR meter reads 6 kVAR on the same circuit. The apparent power is?

A. 10 kVA

- B. 14 kVA
- C. 2 kVA
- D. 48 kVA

8. The purpose of a freewheeling (flyback) diode across a DC relay coil is to?

- A. Increase the relay's pull-in current
- B. Speed up relay dropout time
- C. Clamp the inductive voltage spike when the coil is de-energized
- D. Protect the relay contacts from overcurrent

9. In a three-phase system, the sequence of voltages A-B-C reaching their peak values in order is called?

- A. Zero sequence
- B. Negative sequence
- C. Positive sequence
- D. Forward rotation only

10. A step-down transformer has a turns ratio of 10:1. If the primary impedance is  $1,000\Omega$ , the reflected secondary impedance is?

- A.  $10\Omega$
- B.  $100\Omega$
- C.  $10,000\Omega$
- D.  $1,000\Omega$

11. Kirchhoff's Voltage Law (KVL) states that?

- A. The sum of all currents entering a node equals the sum leaving
- B. Voltage across parallel components is always equal
- C. The algebraic sum of all voltages around a closed loop equals zero
- D. Current in a series circuit is proportional to resistance

12. The term "form factor" of an AC waveform refers to?

- A. The ratio of peak to average value
- B. The ratio of average to RMS value
- C. The ratio of RMS to average value
- D. The ratio of peak to RMS value

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

13. Per NEC 210.8(B), GFCI protection is required for all 15A and 20A, 125V receptacles installed in commercial and industrial kitchens?

- A. Only if within 3 feet of a sink
- B. Yes — all receptacles in commercial kitchens require GFCI protection regardless of distance from water sources
- C. Only for receptacles on countertops
- D. Only when installed within 6 feet of food preparation equipment

14. The maximum number of overcurrent devices permitted in a lighting and appliance branch circuit panelboard per NEC 408.54 is?

- A. 30 overcurrent devices total
- B. 42 overcurrent devices total
- C. No limit — determined by bus ampacity only
- D. 24 overcurrent devices total

15. Type MI (mineral insulated) cable is listed for use in?

- A. Dry locations only, up to 600V
- B. Hazardous locations, wet locations, direct burial, and high-temperature applications
- C. Underground service entrance use only
- D. Interior exposed wiring in commercial buildings only

16. The purpose of a listed "weatherproof" cover on an outdoor receptacle is to?

- A. Provide GFCI protection for the receptacle
- B. Protect the receptacle from weather while a cord is plugged in — an "in-use" cover maintains the weatherproof rating with a cord inserted
- C. Satisfy NEC requirements for wet location receptacles in all cases
- D. Provide UV protection for the receptacle device

17. Per NEC 250.50, which of the following must be bonded together at the service to form the grounding electrode system?

- A. Ground rods only
- B. All available grounding electrodes including metal water pipe, building steel, ground rods, and concrete-encased electrodes
- C. Ground rods and metal water pipe only
- D. Only listed grounding electrodes installed specifically for the electrical system

18. The maximum distance between conduit supports for 1-inch rigid metal conduit per NEC Table 344.30(B)(2) is?

- A. 8 feet
- B. 10 feet
- C. 12 feet
- D. 6 feet

19. Under NEC 230.95(C), the ground fault protection of equipment on a 480Y/277V service must be tested?

- A. Annually by a licensed electrician
- B. Every 3 years per manufacturer requirements
- C. When first installed using a primary injection test method to verify correct operation
- D. Monthly using the test button on the GFPE device

20. A multi-wire branch circuit (MWBC) requires that all ungrounded conductors be?

- A. Opened simultaneously by a single breaker or a handle-tied two-pole breaker — preventing one hot leg from remaining energized when a circuit opens for servicing
- B. Protected by individual single-pole breakers for each leg
- C. The same AWG as the neutral conductor
- D. Identified with different colors at every termination point

21. The purpose of conduit fill limitations in NEC Chapter 9 is to?

- A. Prevent voltage drop from excessive conductor length in the conduit
- B. Limit conductor temperature rise from stacked conductors in a common raceway

C. Both A and B

D. Allow conductors to be pulled without damage and prevent insulation damage from excessive pulling tension and heat — applying to installation conditions, not ongoing operation

22. Under NEC 424.19, electric space heating equipment must have a disconnecting means that is?

A. Located within sight of the heating unit only

B. Within sight of the unit or capable of being locked in the open position — and must disconnect all ungrounded conductors simultaneously

C. Rated at least 125% of the heater's rated load

D. A listed appliance switch rated for the heater current

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

23. The purpose of a "load flow" (power flow) study is to?

A. Calculate steady-state bus voltages, line currents, and power flows throughout the system under various loading conditions — identifying overloaded equipment and voltage violations before they occur in service

B. Determine maximum fault current at each bus under bolted fault conditions

C. Evaluate protective relay coordination for the system

D. Model transient voltage behavior during switching events

24. In a high-voltage cable system, "partial discharge" activity inside the cable insulation indicates?

A. Normal operating condition — all cables experience some partial discharge

B. Cable has reached its rated current carrying capacity

C. Cable insulation is approaching its thermal limit

D. Voids, contaminants, or insulation defects where local electric field exceeds the air breakdown strength — indicating insulation deterioration that will progress to complete breakdown

25. The purpose of a "motor bus transfer" relay (ANSI device 86) is to?

A. Automatically reclose a tripped feeder breaker after a time delay

B. Lock out a circuit after a protective relay operation — requiring manual reset before re-energization to prevent automatic restart following a fault

C. Transfer motor loads between buses during peak demand periods

D. Monitor bus voltage and transfer load when voltage drops below setpoint

26. In power system protection, the "time-current characteristic" (TCC) curve of an overcurrent relay represents?

A. The relay's operating voltage range vs. time

B. The relationship between fault current magnitude and the time the relay takes to operate — used to coordinate relay operation with upstream and downstream devices

C. The relay's power consumption vs. ambient temperature

D. The relay's reset time after the fault current is interrupted

27. The purpose of a "neutral displacement" voltage in an ungrounded or high-impedance grounded system is to?

A. Provide a reference for phase voltage measurement

B. Indicate normal system operation within acceptable limits

C. Monitor load unbalance between the three phases

D. Indicate a single line-to-ground fault — the neutral shifts from its normal center-of-triangle position, causing the faulted phase voltage to drop toward zero and the unfaulted phases to rise toward line voltage

28. A 13.8 kV bus has an available three-phase fault current of 20 kA. The bolted fault MVA is approximately?

- A. 276 MVA
- B. 400 MVA
- C. 478 MVA
- D. 550 MVA

29. The purpose of an "undervoltage" relay (ANSI 27) on a motor bus is to?

- A. Trip motor contactors when bus voltage drops below a threshold — preventing motors from stalling and drawing excessive current during a sustained undervoltage condition that could cause thermal damage
- B. Detect open phase conditions on the motor bus
- C. Provide backup protection for the bus differential relay
- D. Monitor voltage unbalance between phases

30. In a three-phase power system, "negative sequence" currents are caused by?

- A. Ground faults on the system
- B. Voltage or current unbalance — appearing in induction motors as counter-rotating magnetic flux that produces additional rotor heating disproportionate to the unbalance percentage
- C. Capacitor bank switching transients
- D. Harmonic currents from nonlinear loads only

31. The purpose of a power transformer's "delta tertiary" winding in a wye-wye transformer bank is to?

- A. Provide an additional voltage level for auxiliary loads
- B. Improve transformer voltage regulation under unbalanced loading

- C. Provide a circulating path for zero-sequence and third-harmonic currents — preventing them from appearing on the wye windings and distorting the system voltage waveform
- D. Reduce transformer core losses at light load

32. The purpose of a "synchrocheck" relay (ANSI 25) is to?

- A. Monitor generator speed during startup and trip on overspeed
- B. Verify generator frequency matches the bus frequency before closing
- C. Monitor transformer tap changer position during voltage regulation
- D. Verify that voltage magnitude, frequency, and phase angle are within acceptable limits before permitting a breaker to close — preventing out-of-phase switching that could damage generators and transformers

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

33. A synchronous generator is operating at rated load. To increase its reactive power output (leading PF to the bus), the operator should?

- A. Increase prime mover fuel input
- B. Decrease prime mover speed
- C. Decrease field excitation current
- D. Increase field excitation current — over-excitation causes the generator to supply reactive power (capacitive) to the system

34. The purpose of a motor's "enclosure" designation (TEFC, ODP, TENV) is to?

- A. Define the motor's insulation class for temperature rating
- B. Specify the degree of protection the motor frame provides against the environment — determining suitability for specific ambient conditions

- C. Indicate the motor's cooling method and efficiency rating
- D. Define the motor's mounting configuration for installation

35. In a star-delta (Y- $\Delta$ ) motor starter, the motor is initially connected in wye to?

- A. Reduce starting voltage to 58% of line voltage — reducing starting current to approximately 33% of full-voltage starting current while reducing starting torque to 33% also
- B. Provide maximum starting torque at reduced current
- C. Allow the motor to start unloaded before switching to delta
- D. Protect the motor windings during the transition from wye to delta

36. The purpose of a "phase sequence relay" in a motor control circuit is to?

- A. Monitor motor current for phase unbalance during running
- B. Detect single-phasing of the motor supply during operation
- C. Verify correct phase sequence before permitting motor startup — preventing motor rotation in the wrong direction which could damage the driven equipment or process
- D. Protect the motor from phase-to-phase short circuits during starting

37. A 480V, 3-phase induction motor is operated on a 460V supply. The effect on motor torque is?

- A. Torque increases proportionally with the lower voltage
- B. Torque remains unchanged — induction motors are constant torque devices
- C. Torque increases because reduced voltage reduces losses
- D. Torque decreases proportionally to the square of the voltage ratio — at  $460/480 = 0.958$ , torque =  $0.958^2 = 0.917$ , or approximately 8.3% reduction in available torque

38. The purpose of a motor's "starting duty" cycle rating is to?

- A. Define the maximum starting torque the motor can develop
- B. Limit the motor starting current to protect branch circuit conductors
- C. Specify the number of starts per hour and required cool-down periods — preventing thermal damage to rotor bars and stator insulation from repeated starting inrush currents
- D. Define the motor's locked rotor withstand time at rated voltage

39. In a VFD application, "slip compensation" adjusts the output frequency to?

- A. Prevent the motor from exceeding synchronous speed during regeneration
- B. Maintain constant motor speed regardless of DC bus voltage variations
- C. Compensate for the increase in rotor slip under load — boosting output frequency slightly above the set speed reference to maintain the actual shaft speed at the desired value
- D. Reduce motor acoustic noise at low speeds by modulating carrier frequency

40. The purpose of a motor control center's (MCC) "unit space" or "blank section" is to?

- A. Reserve space for future motor starter additions without requiring bus extensions or new MCC sections — the bus is pre-wired and terminated, ready for future unit installation
- B. Provide ventilation space between large motor starters
- C. Store spare parts and tools for MCC maintenance
- D. Provide space for test equipment during commissioning

41. A 100 HP, 480V, 3-phase motor with 90% efficiency and 0.88 PF draws full-load current of approximately?

- A. 104A

- B. 120A
- C. 138A
- D. 124A

42. The purpose of a "peak demand controller" in a facility with large motor loads is to?

- A. Automatically shed non-critical loads when demand approaches the utility demand setpoint — preventing peak demand charges by keeping the 15-minute demand below the contract threshold
- B. Reduce motor starting current by staggering starts
- C. Monitor motor efficiency and alert operators to degraded performance
- D. Control motor speed to reduce energy consumption during off-peak hours

43. In a permanent magnet DC motor, speed control is achieved by?

- A. Varying field current through the permanent magnets
- B. Varying the armature voltage — since field flux is fixed by the permanent magnets, speed is proportional to armature voltage ( $N \propto V_a \div \Phi$ , with  $\Phi$  constant)
- C. Varying the load connected to the motor shaft
- D. Varying supply frequency to the armature circuit

44. The purpose of a motor's "insulation class" designation (Class B, F, H) is to?

- A. Define the motor's ability to withstand mechanical vibration
- B. Specify the maximum allowable winding temperature — Class B = 130°C, Class F = 155°C, Class H = 180°C total temperature including ambient and rise
- C. Indicate the motor's resistance to chemical environments
- D. Define the motor's duty cycle for continuous vs. intermittent operation

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

45. The purpose of a "contact resistance" test on a circuit breaker using a micro-ohmmeter (DLRO) is to?

- A. Verify the breaker's rated interrupting capacity under fault conditions
- B. Measure the resistance across the closed contacts — high contact resistance causes  $I^2R$  heating that leads to overheating, contact welding, and eventual failure
- C. Test the breaker's trip unit calibration at rated current
- D. Verify the breaker's mechanical operation cycle count

46. When troubleshooting a transformer that produces a humming noise louder than normal, the most likely cause is?

- A. Core lamination looseness, DC component in the supply voltage, or operation above rated voltage — all causing increased magnetostriction vibration in the core
- B. Overloading of the secondary winding only
- C. Low oil level in the transformer tank
- D. Loose connections on the primary terminals

47. The purpose of performing a "ground mat" test at a substation is to?

- A. Verify the continuity of the substation fence grounding system
- B. Test the surge arrester grounding connections
- C. Measure the substation grounding electrode resistance only
- D. Measure the step and touch potential at the substation ground grid — verifying personnel safety during fault conditions when fault current flows through the ground mat

48. A three-phase transformer bank shows unequal secondary voltages with correct primary voltages applied. The most likely cause is?

- A. Primary overcurrent protection operating on one phase
- B. A shorted or open turn in one transformer winding — changing that transformer's turns ratio and producing unequal secondary voltages
- C. Load unbalance on the secondary side
- D. Incorrect transformer connections during installation

49. The purpose of a "sweep frequency response analysis" (SFRA) test on a power transformer is to?

- A. Measure transformer core loss at various frequencies
- B. Detect physical changes to the transformer windings — movement, deformation, or damage from through-fault forces — by comparing the frequency response against a baseline fingerprint
- C. Test the transformer's response to lightning impulse voltages
- D. Verify transformer cooling system performance at different load levels

50. When a ground fault relay operates but no fault is found on the protected system, the most likely cause of the spurious trip is?

- A. The relay setpoint is set too high for the system's normal charging current
- B. The relay is malfunctioning and requires replacement
- C. Normal charging current of the system's cable capacitance exceeds the relay's pickup setting — the relay must be set above the system's total zero-sequence charging current to avoid nuisance tripping
- D. A transient overvoltage caused the relay to operate momentarily

51. The purpose of a "battery impedance test" on a UPS or substation battery bank is to?

- A. Measure the battery's state of charge

- B. Test the battery charger's output impedance
- C. Verify the battery bank's capacity in ampere-hours
- D. Identify failing cells — increased internal impedance indicates sulfation, dryout, or plate degradation before the cell fails completely under discharge conditions

52. When performing a high-potential DC test on a cable, a current that starts high and decreases exponentially before stabilizing indicates?

- A. The cable insulation is failing and will not pass the test
- B. The cable has a direct fault to ground
- C. Normal cable behavior — the initial high current charges the cable capacitance; stabilization indicates the insulation leakage current only, which should be low for good insulation
- D. The test voltage is too high for the cable's insulation rating

53. The purpose of an "oil interfacial tension" (IFT) test on transformer oil is to?

- A. Measure the oil's viscosity for pump sizing
- B. Determine the oil's dielectric strength at operating temperature
- C. Measure dissolved water content in the oil
- D. Detect oxidation products (polar contaminants) in the oil — low IFT indicates oil aging and the presence of polar compounds that increase dielectric losses and accelerate insulation degradation

54. When a VFD displays a "DC bus overvoltage" fault during motor deceleration, the correct corrective action is to?

- A. Increase the DC bus capacitor bank size
- B. Replace the IGBTs in the inverter section
- C. Extend the deceleration ramp time or install a dynamic braking resistor — the fault indicates regenerative energy is raising the DC bus voltage above the trip threshold faster than it can be dissipated

D. Reduce the motor's rated voltage in the VFD parameters

### **MECHANICAL EQUIPMENT (Questions 55–63)**

55. The purpose of a pump's "affinity laws" in variable speed applications is to?

A. Predict how flow, head, and power change with speed — flow varies proportionally with speed, head varies as the square of speed, and power varies as the cube of speed

B. Calculate pump bearing life at different speeds

C. Determine pump efficiency at off-design conditions

D. Predict cavitation onset at reduced speed

56. In a steam power plant, the purpose of a "condenser" is to?

A. Cool superheated steam before it enters the turbine

B. Separate steam from condensate in the return system

C. Store condensate for return to the boiler feedwater system

D. Condense exhaust steam from the turbine — creating a vacuum that increases the pressure differential across the turbine and maximizes power output

57. The purpose of a boiler's "steam drum internals" (chevron separators, cyclone separators) is to?

A. Separate steam from water in the drum — delivering dry steam to the superheater or steam main while returning separated water to the downcomer circuit

B. Control steam flow rate to the turbine

C. Distribute feedwater evenly across the drum

D. Provide storage volume for sudden load changes

58. The purpose of a gas turbine's "inlet air filter" is to?

- A. Reduce inlet air temperature for improved compressor efficiency
- B. Remove moisture from combustion air before compression
- C. Control air flow rate to match fuel flow during load changes
- D. Remove particulates and contaminants from inlet air — protecting compressor blades from erosion and fouling that reduces efficiency and increases maintenance costs

59. In a centrifugal chiller, the purpose of the oil separator in the refrigerant circuit is to?

- A. Remove water from the refrigerant after condenser leakage
- B. Filter metal particles from the refrigerant circuit
- C. Cool lubricating oil before return to the compressor bearings
- D. Separate lubricating oil from the refrigerant before it enters the evaporator — preventing oil fouling of evaporator heat transfer surfaces that would reduce chiller efficiency

60. The purpose of a boiler's "superheater" is to?

- A. Raise steam temperature above saturation temperature at the operating pressure — increasing steam enthalpy, improving turbine efficiency, and eliminating moisture at turbine exhaust stages
- B. Increase steam pressure above the drum operating pressure
- C. Provide emergency steam storage for load swings
- D. Heat the combustion air for improved combustion efficiency

61. A centrifugal pump operating at 1,750 RPM produces 500 GPM at 100 ft TDH. If speed is reduced to 1,400 RPM, the new flow and head are approximately?

- A. 350 GPM, 70 ft TDH

- B. 500 GPM, 64 ft TDH
- C. 400 GPM, 64 ft TDH
- D. 400 GPM, 100 ft TDH

62. The purpose of a reciprocating compressor's "valve unloader" vs. a "cylinder unloader" is to?

- A. Valve unloader controls compressor speed; cylinder unloader controls inlet pressure
- B. Both provide the same function — reducing compressor output capacity
- C. Valve unloaders hold suction valves open to prevent compression; cylinder unloaders bypass the discharge back to suction — both reduce capacity but by different mechanisms
- D. Valve unloaders are used only on single-acting cylinders; cylinder unloaders on double-acting only

63. The purpose of an "oil wedge" in a hydrodynamic journal bearing is to?

- A. Provide a physical barrier between shaft and bearing surface during startup
- B. Supply oil to the bearing during the transition from boundary to hydrodynamic lubrication
- C. Apply pre-load to the bearing to prevent shaft vibration
- D. Carry the full shaft load on a thin film of pressurized oil — the rotating shaft pumps oil between itself and the bearing, generating a pressure wedge that lifts the shaft off the bearing surface

#### **FLUID SYSTEMS (Questions 64–72)**

64. In an HVAC system, the term "sensible heat ratio" (SHR) of a cooling coil refers to?

- A. The ratio of latent heat removed to total heat removed
- B. The ratio of sensible heat removed to total heat (sensible + latent) removed — indicating how much of the cooling is reducing temperature vs. removing moisture
- C. The ratio of supply air temperature rise to return air temperature

D. The ratio of coil heat transfer area to airflow rate

65. The purpose of a "static pressure reset" control strategy in a VAV system is to?

A. Maintain maximum static pressure in the ductwork at all times for system reliability

B. Prevent duct pressure from dropping below minimum during high-load periods

C. Reset supply fan speed to minimum regardless of zone demand

D. Reduce duct static pressure setpoint as zone demand decreases — allowing the supply fan to run slower and save energy when most VAV boxes are partially closed

66. In a steam system, "steam hammer" (water hammer) is caused by?

A. Excessive steam velocity in oversized steam mains

B. Steam pressure fluctuations from boiler load swings

C. Slugs of condensate entrained in the steam flow colliding with pipe fittings and valves — caused by inadequate drainage, flooded steam traps, or rapid valve opening that sweeps standing condensate

D. Thermal expansion of steam mains during warm-up

67. The purpose of a cooling tower's "drift eliminators" is to?

A. Prevent ice formation on the fan blades during cold weather operation

B. Remove dissolved solids from the recirculating water before it falls to the basin

C. Prevent water droplets entrained in the leaving air stream from being carried outside the tower — reducing water loss and preventing Legionella-contaminated water from being dispersed to the surrounding area

D. Reduce the noise level of the falling water in the tower basin

68. In a hydronic system, a differential pressure transmitter connected across the system pump measures?

- A. Static pressure at the pump suction only
- B. Total system pressure loss in the distribution piping
- C. Pump suction pressure only for cavitation prevention
- D. The difference between pump discharge and suction pressure — used to control pump speed in a variable flow system by maintaining a constant differential pressure setpoint

69. The purpose of a boiler's "continuous blowdown" line vs. "intermittent (bottom) blowdown" is to?

- A. Continuous blowdown removes sludge; intermittent blowdown removes dissolved solids
- B. Both continuous and intermittent blowdown serve identical functions
- C. Continuous blowdown is only used on high-pressure boilers above 600 psig
- D. Continuous blowdown removes dissolved solids from near the water surface to control conductivity; intermittent blowdown removes settled sludge from the mud drum or lower headers

70. In a refrigeration system, the purpose of a "liquid line filter-drier" is to?

- A. Remove superheat from the refrigerant leaving the condenser
- B. Separate oil from liquid refrigerant before the expansion device
- C. Remove moisture and particulates from liquid refrigerant — preventing moisture from freezing at the expansion valve and protecting the expansion valve and compressor from contamination
- D. Subcool the liquid refrigerant before the expansion valve

71. The purpose of a "pressurization pump" (jockey pump) in a fire suppression system is to?

- A. Supply water flow during a sprinkler activation event

- B. Maintain system pressure and detect small leaks — if pressure drops slowly, the jockey pump cycles to restore it; if pressure drops faster than the jockey pump can restore, the main fire pump starts automatically
- C. Pre-pressurize the system before the main fire pump starts
- D. Provide backup flow capacity if the main fire pump fails to start

72. In a chilled water system, the "chilled water reset" control strategy raises the chilled water supply temperature setpoint when?

- A. Outdoor air temperature drops — reducing cooling load and allowing higher chilled water temperature without sacrificing dehumidification
- B. Building occupancy increases above the design level
- C. Chiller lift exceeds its design value
- D. Cooling load decreases — allowing higher CHW supply temperature that reduces chiller lift, improves chiller COP, and saves compressor energy while still satisfying all zone cooling demands

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

73. The purpose of a "cable tray fill" limitation per NEC Article 392 is to?

- A. Prevent cable overloading during pulling operations
- B. Ensure adequate cable identification and color coding
- C. Limit installation cost by restricting cable quantities
- D. Prevent cable overheating by limiting the total cross-sectional area of cables — maintaining adequate airflow around cables for heat dissipation within the tray

74. The correct procedure when splicing copper conductors using mechanical compression connectors in a junction box is to?

- A. Twist conductors together before inserting into the connector barrel
- B. Apply anti-oxidant compound to the conductor before crimping
- C. Use the connector manufacturer's specified crimping tool and die set — using an incorrect die produces an incomplete crimp that has high resistance and may pull out under tension
- D. Use the correct die set for the connector, strip the correct length of insulation, fully insert the conductor, and apply the specified number of crimps per the connector manufacturer's installation instructions

75. When using an aerial lift (boom truck or scissor lift) near energized overhead lines, the minimum approach distance for an uninsulated aerial lift working near 15 kV distribution lines is?

- A. 3 feet
- B. 10 feet — per OSHA 1926.1407 and NFPA 70E, uninsulated equipment must maintain minimum approach distances from energized lines; for lines 15 kV, the minimum is 10 feet
- C. 6 feet
- D. 15 feet

76. The purpose of a "running line pull" calculation before pulling cable through conduit is to?

- A. Verify the conduit fill percentage will not exceed NEC limits
- B. Determine the conduit size required for the cable
- C. Schedule the cable pulling crew size needed for the job
- D. Verify the pulling tension will not exceed the cable's maximum allowable pulling tension — preventing conductor stretching, insulation damage, and jacket tears

77. The purpose of using "explosion-proof" electrical fixtures in a Class I, Division 1 hazardous location instead of standard fixtures is to?

- A. Provide higher lumen output for improved visibility in hazardous areas
- B. Reduce the risk of electrical sparks igniting surrounding flammable gases

C. Satisfy OSHA requirements for grounding in hazardous locations

D. Contain any internal arcing or explosion within the fixture housing — preventing ignition of the surrounding flammable atmosphere while allowing normal fixture operation

78. When a load is being hoisted with a crane, the crane operator must?

A. Maintain constant communication with the rigger only

B. Operate at maximum speed to minimize load swing

C. Position the hook directly above the load center of gravity before lifting to minimize load swing and stress on the rigging

D. Verify load weight, confirm rigging is properly attached, ensure the load path is clear, maintain visual contact or radio communication with the signal person, and never exceed the crane's rated capacity at the operating radius

79. The purpose of a "cable pulling eye" (Kellems grip or pulling eye) on a cable end is to?

A. Provide a strain relief where the cable exits the conduit

B. Allow the cable to be tested for continuity before installation

C. Mark the cable end for phase identification during termination

D. Transfer pulling tension to the cable's conductor or overall jacket — distributing the pulling force over the cable's cross-section to prevent conductor stretch or insulation damage during long pulls

80. The correct method for measuring the resistance of a ground rod per IEEE 81 is the?

A. Fall-of-potential (three-point) method — placing current and potential electrodes at specified distances from the ground rod and measuring the resistance vs. distance curve to identify the plateau region representing true earth resistance

B. Two-point method using the facility's electrical panel as the reference

C. Clamp-on meter method only — no auxiliary electrodes required

D. Dead earth method using another ground rod as the reference electrode

## **HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)**

81. The purpose of OSHA's "hierarchy of controls" for chemical hazards lists substitution as the second priority because?

A. Substitution is always cheaper than engineering controls

B. Substitution is always easier to implement than elimination

C. Substitution replaces a hazardous chemical or process with a less hazardous one — eliminating or significantly reducing the hazard at the source, which is more reliable than engineering controls that manage the hazard without removing it

D. Substitution satisfies EPA regulatory requirements for chemical reduction

82. Under OSHA 1910.1200 (HazCom), the GHS "Health Hazard" pictogram (exclamation mark) indicates?

A. The chemical is immediately dangerous to life or health (IDLH)

B. Less serious health effects including skin/eye irritation, skin sensitization, acute toxicity (harmful), respiratory tract irritation, and narcotic effects

C. The chemical causes cancer or reproductive toxicity

D. The chemical is a carcinogen or mutagen exclusively

83. The purpose of a facility's "chemical hygiene plan" under OSHA 1910.1450 (laboratory standard) is to?

A. Satisfy EPA requirements for laboratory chemical waste disposal

B. Describe the specific work practices, procedures, and policies to protect laboratory workers from hazardous chemical exposures — including standard operating procedures, exposure control measures, training, and medical consultation provisions

- C. Provide emergency response procedures for laboratory chemical spills only
- D. Document laboratory chemical inventory for EPCRA Tier II reporting

84. Under EPA RCRA, a "conditionally exempt small quantity generator" (CESQG) generates no more than?

- A. 100 kg of hazardous waste per month — and is subject to minimal RCRA requirements compared to small and large quantity generators
- B. 1,000 kg of hazardous waste per month
- C. 500 kg of hazardous waste per month
- D. 250 kg of hazardous waste per month

85. The primary purpose of OSHA's "walking-working surfaces" standard (1910 Subpart D) as it applies to stationary engineers is to?

- A. Define ladder safety requirements only
- B. Establish requirements for floors, platforms, catwalks, stairways, ladders, and elevated work surfaces — preventing falls, which are among the leading causes of serious injuries in industrial facilities
- C. Specify guardrail height requirements for mezzanines only
- D. Provide requirements for scissor lift and aerial work platform operation

86. Under the Toxic Substances Control Act (TSCA), the purpose of an "inventory notification" for a new chemical substance is to?

- A. Notify the EPA before manufacturing or importing a chemical not already on the TSCA Chemical Substance Inventory — allowing EPA to evaluate risks before the chemical enters commerce
- B. Report annual production volumes of listed chemicals to the EPA
- C. Satisfy state right-to-know requirements for new chemical introductions
- D. Register the chemical for use in food contact applications

87. The purpose of OSHA's "control of hazardous energy" standard (1910.147) covers all of the following energy sources EXCEPT?

- A. Electrical energy
- B. Hydraulic energy
- C. Thermal energy from steam
- D. Ionizing radiation from radioactive materials — which is covered separately under 29 CFR 1910.1096 (ionizing radiation standard)

88. Under EPCRA Section 313, the purpose of a Toxics Release Inventory (TRI) Form R report is to?

- A. Report all hazardous chemical inventories above threshold quantities to the LEPC
- B. Report annual releases and transfers of listed toxic chemicals to the EPA — providing public information about toxic chemical releases from manufacturing and other covered facilities
- C. Satisfy RCRA hazardous waste reporting requirements for large quantity generators
- D. Report accidental chemical releases above reportable quantities to the NRC

89. The purpose of an "environmental impact assessment" (EIA) before a facility expansion project is to?

- A. Satisfy OSHA requirements for new process safety reviews
- B. Calculate the facility's carbon footprint for voluntary reporting
- C. Identify and evaluate potential environmental consequences of the project — including impacts on air quality, water resources, habitats, and community health — before construction begins, allowing mitigation measures to be incorporated into the project design
- D. Document compliance with existing environmental permits during construction

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

90. Under NFPA 70E, which of the following tasks on energized 480V equipment requires PPE Category 2 minimum?

- A. Reading a panel meter through the closed panel door
- B. Inserting or removing a plug-in circuit breaker in a 480V MCC with the door open and cover removed
- C. Working on the load side of an open 480V disconnect with LOTO applied
- D. Resetting a tripped breaker with the panel door closed

91. The purpose of rubber insulating gloves' "class" designation (Class 00, 0, 1, 2, 3, 4) is to?

- A. Indicate the glove's puncture resistance rating
- B. Specify the maximum use voltage the gloves provide protection for — Class 00 = 500V AC, Class 0 = 1,000V AC, Class 2 = 17,000V AC, Class 4 = 36,000V AC
- C. Define the glove's arc flash protection level in cal/cm<sup>2</sup>
- D. Indicate the glove material — natural rubber vs. synthetic rubber

92. Under OSHA 1910.147, a "complex LOTO" procedure involving multiple energy sources requires?

- A. A separate lockout for each energy source applied by the same authorized employee
- B. Supervisor authorization before each application of the procedure
- C. A third-party LOTO audit before any work begins
- D. A written equipment-specific procedure identifying each energy source, isolation point, and verification method — ensuring any authorized employee can safely isolate the equipment without relying on memory

93. When a worker is found unresponsive after an electrical contact incident, the rescuer should first?

- A. Ensure the scene is safe — confirm the victim is no longer in contact with an energized source before approaching, then call 911 and begin CPR if the victim is not breathing
- B. Begin chest compressions immediately without checking scene safety
- C. Check for pulse for 60 seconds before beginning CPR
- D. Move the victim away from the electrical equipment before assessing

94. The purpose of "task-based" arc flash risk assessment per NFPA 70E 130.5 is to?

- A. Assign a fixed PPE category to all tasks at a facility regardless of equipment condition
- B. Calculate incident energy for every piece of equipment in the facility
- C. Use arc flash PPE tables only for tasks listed in the tables
- D. Evaluate the specific hazard for each task — considering the likelihood of arc ignition, equipment condition, and available protective measures — to determine appropriate PPE rather than defaulting to worst-case PPE for all tasks

95. The purpose of a "hot work permit" system per NFPA 51B is to?

- A. Authorize welding equipment use in non-hazardous locations only
- B. Provide a written record of hot work for insurance documentation
- C. Ensure hazards are identified, combustibles are removed or protected, fire watches are assigned, and fire suppression equipment is available before any hot work begins — the permit is the authorization for the work to proceed
- D. Satisfy OSHA welding standard requirements for open-flame work

96. Under NFPA 70E, the purpose of "approach boundaries" (limited, restricted, prohibited) is to?

- A. Define the minimum distances for arc flash protection at each voltage level

- B. Define zones of increasing shock hazard around exposed energized conductors — establishing who may enter each zone and what protection is required based on their qualifications and the voltage involved
- C. Specify the minimum PPE category for each boundary zone
- D. Define the safe working distance for arc flash PPE selection

97. When a facility experiences a partial power outage affecting some but not all circuits from the same panel, the most likely cause is?

- A. A tripped main breaker with some circuits protected by a separate source
- B. Utility voltage unbalance affecting only some circuits
- C. A failed neutral connection causing voltage redistribution between phases
- D. Loss of one phase at the service entrance or main panel — affecting all single-phase circuits connected to the lost phase while circuits on the other phases remain energized

98. The purpose of NFPA 72's "pathway survivability" requirement for emergency communication systems is to?

- A. Ensure communication systems operate at elevated temperatures during a fire — requiring circuit conductors and equipment in the fire area to maintain functionality for a minimum period
- B. Provide redundant communication pathways for all alarm signals
- C. Ensure emergency communication systems can withstand seismic events
- D. Require fiber optic communication between fire alarm control panels only

99. The purpose of testing emergency lighting battery units monthly per NEC 700.3 is to?

- A. Fully discharge the battery to test its capacity under load
- B. Test the transfer switch operation from normal to emergency power
- C. Verify the unit activates and provides illumination when normal power is interrupted — a 30-second functional test confirms the battery, lamp, and transfer circuit are operational

D. Calibrate the battery charger to ensure full charge is maintained

100. The most effective method for a stationary engineer to stay current with changes to the NEC, NFPA 70E, and OSHA electrical standards is to?

A. Participate in ongoing continuing education, code update seminars, and professional association activities — code cycles occur every 3 years and significant changes in each edition can affect equipment selection, installation requirements, and safe work practices

B. Read the summary of changes section in each new code edition only

C. Rely on equipment manufacturers to notify users of code changes affecting their products

D. Wait for the local AHJ to issue notices about code changes before updating work practices

# PRACTICE EXAM 17 — ANSWER KEY AND FULL EXPLANATIONS

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## ELECTRICAL FUNDAMENTALS (Questions 1–12)

- 1. Correct Answer: B — 31.25A:**  $I = P \div (V \times PF) = 12,000 \div (480 \times 0.8) = 12,000 \div 384 = 31.25\text{A}$ . The power factor reduces the effective work done per ampere, requiring more current to deliver the same real power.
- 2. Correct Answer: D — Inductive reactance:** Inductive reactance  $X_L = 2\pi fL$  opposes changes in current by generating a back-EMF proportional to the rate of current change. Unlike resistance, inductive reactance stores energy in the magnetic field rather than dissipating it as heat.
- 3. Correct Answer: D —  $3\Omega$ :** For  $n$  equal resistors in parallel:  $R_{eq} = R \div n = 9 \div 3 = 3\Omega$ . Each parallel path provides an additional route for current, reducing total resistance proportionally.
- 4. Correct Answer: C — 25J:** Energy stored in an inductor:  $E = \frac{1}{2}LI^2 = \frac{1}{2} \times 2 \times 5^2 = \frac{1}{2} \times 2 \times 25 = 25\text{J}$ . This energy is stored in the magnetic field and released when current decreases.
- 5. Correct Answer: B — Leads voltage by  $90^\circ$ :** In a purely capacitive circuit, current must flow to charge the capacitor before voltage can rise — current reaches its peak  $90^\circ$  before voltage. The mnemonic "ICE" (current leads voltage in capacitive circuits) helps remember this relationship.
- 6. Correct Answer: D — 10A:**  $I_{RMS} = I_{peak} \div \sqrt{2} = 14.14 \div 1.414 = 10\text{A}$ . RMS current produces the same heating effect in a resistor as an equivalent DC current of the same value.
- 7. Correct Answer: A — 10 kVA:**  $S = \sqrt{(P^2 + Q^2)} = \sqrt{(8^2 + 6^2)} = \sqrt{(64 + 36)} = \sqrt{100} = 10\text{ kVA}$ . The power triangle relationship  $S^2 = P^2 + Q^2$  is the AC power equivalent of the Pythagorean theorem.
- 8. Correct Answer: C — Clamp the inductive voltage spike when the coil is de-energized:** When relay coil current is interrupted, the collapsing magnetic field induces a flyback voltage ( $L \times di/dt$ ) that can reach hundreds of volts — damaging transistors and other switching devices. The freewheeling diode provides a recirculating path for this energy, clamping the voltage to one diode drop above the supply rail.
- 9. Correct Answer: C — Positive sequence:** Positive sequence (A-B-C) is the normal phase rotation of a balanced three-phase system. Negative sequence (A-C-B) results from phase reversal or unbalance. Zero sequence currents are equal in all three phases and flow through the neutral — associated with ground faults.

**10. Correct Answer: A — 10Ω:** Impedance transforms by the square of the turns ratio:  $Z_{\text{secondary}} = Z_{\text{primary}} \div (N1/N2)^2 = 1,000 \div 10^2 = 1,000 \div 100 = 10\Omega$ . This impedance transformation property is used in matching circuits to maximize power transfer between source and load.

**11. Correct Answer: C — The algebraic sum of all voltages around a closed loop equals zero:** KVL is a statement of energy conservation — the sum of voltage rises (source EMFs) equals the sum of voltage drops (resistive and reactive drops) around any closed path. It applies to both DC and AC circuits.

**12. Correct Answer: C — The ratio of RMS to average value:** Form factor =  $V_{\text{RMS}} \div V_{\text{avg}}$ . For a sinusoidal waveform, form factor =  $(V_{\text{peak}}/\sqrt{2}) \div (2V_{\text{peak}}/\pi) = \pi/(2\sqrt{2}) \approx 1.11$ . Form factor is used in calculating meter errors when AC meters calibrated for sinusoidal waveforms measure non-sinusoidal signals.

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

**13. Correct Answer: B — Yes — all receptacles in commercial kitchens require GFCI protection regardless of distance from water:** NEC 210.8(B)(2) requires GFCI protection for all 15A and 20A, 125V receptacles installed in commercial and industrial kitchens — no distance restriction applies. The commercial kitchen requirement was expanded in the 2014 NEC to cover all receptacles regardless of proximity to water sources.

**14. Correct Answer: B — 42 overcurrent devices total:** NEC 408.54 limits lighting and appliance branch circuit panelboards to a maximum of 42 overcurrent devices (circuits). Two-pole breakers count as two overcurrent devices. This limit drove the development of "loadcenters" with more circuit capacity for large residential and light commercial installations.

**15. Correct Answer: B — Hazardous locations, wet locations, direct burial, and high-temperature applications:** Type MI cable consists of copper conductors in a compressed mineral oxide (magnesium oxide) insulation surrounded by a copper or alloy steel sheath. Its all-inorganic construction makes it suitable for the most demanding environments — including nuclear facilities, airports, tunnels, and high-temperature industrial applications up to 250°C.

**16. Correct Answer: B — Protect the receptacle from weather while a cord is plugged in — an in-use cover maintains the weatherproof rating with a cord inserted:** NEC 406.9(B)(1) requires receptacles in wet locations to be protected by an enclosure that is weatherproof whether or not the attachment plug cap is inserted. Standard "flip-lid" covers only protect the receptacle when nothing is plugged in — an "extra duty" in-use cover (box cover) is required for wet locations.

**17. Correct Answer: B — All available grounding electrodes including metal water pipe, building steel, ground rods, and concrete-encased electrodes:** NEC 250.50 requires all grounding electrodes described in 250.52 that are present at a building to be bonded together to form the grounding electrode system. Using all available electrodes in parallel reduces the overall grounding resistance and provides redundancy.

**18. Correct Answer: B — 10 feet:** NEC Table 344.30(B)(2) requires RMC to be supported within 3 feet of each outlet box, junction box, or cabinet and at maximum intervals of 10 feet. Larger trade sizes permit greater spacing — 1¼" through 1½" may be supported at 12 feet; 2" and larger at 14–20 feet depending on trade size.

**19. Correct Answer: C — When first installed using a primary injection test method to verify correct operation:** NEC 230.95(C) requires the GFPE system to be performance tested when first installed. The test must use a primary injection method to verify the sensor, relay, and trip mechanism all function correctly as a system — the test button on the device only tests the relay, not the sensor or wiring.

**20. Correct Answer: A — Opened simultaneously by a single breaker or a handle-tied two-pole breaker:** NEC 210.4(B) requires the ungrounded conductors of a multi-wire branch circuit to be provided with a means to disconnect them simultaneously at the panelboard. This prevents a shock hazard when one leg is being serviced — without simultaneous disconnection, the neutral could remain energized through the other leg's load.

**21. Correct Answer: D — Allow conductors to be pulled without damage and prevent insulation damage from excessive pulling tension and heat:** NEC Chapter 9 fill limits primarily address installation practicality — pulling tension increases dramatically with fill percentage, and conductors pressed tightly together limit heat dissipation. The 40% fill limit for three or more conductors is an installation limit; ampacity derating addresses the thermal issue during operation.

**22. Correct Answer: B — Within sight of the unit or capable of being locked in the open position — disconnecting all ungrounded conductors simultaneously:** NEC 424.19 requires electric heating equipment to have a disconnecting means that is either within sight of the equipment or capable of being locked in the open position. The disconnect must open all ungrounded conductors simultaneously, ensuring the heating elements are completely de-energized during maintenance.

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

**23. Correct Answer: A — Calculate steady-state bus voltages, line currents, and power flows under various loading conditions:** Load flow studies use iterative numerical methods (Newton-Raphson, Gauss-Seidel) to solve the power flow equations for every bus and branch in the system. Results identify buses with low voltage, overloaded cables and transformers, and reactive power deficiencies — essential for system planning and operational decision-making.

**24. Correct Answer: D — Voids, contaminants, or insulation defects where local electric field exceeds air breakdown strength — indicating deterioration:** Partial discharge in cable insulation occurs at microscopic defects where the local electric field is intensified. Each PD event erodes the surrounding insulation through chemical attack and thermal effects. Online PD monitoring using high-frequency current transformers or offline tan delta testing detects PD activity before complete insulation failure.

**25. Correct Answer: B — Lock out a circuit after a protective relay operation — requiring manual reset before re-energization:** ANSI device 86 (lockout relay) is a hand-reset auxiliary relay that captures

and holds a trip condition after a protective relay operates. It prevents automatic or remote re-energization of a faulted circuit without an operator physically resetting the lockout — ensuring an investigation occurs before the circuit is returned to service.

**26. Correct Answer: B — The relationship between fault current magnitude and the relay's operating time — used for coordination:** The TCC curve plots operating time (y-axis, log scale) vs. current in multiples of pickup (x-axis, log scale). Proper coordination ensures the downstream relay TCC curve lies entirely below the upstream relay TCC curve with an adequate time margin (CTI) at all fault current levels — so the nearest device clears the fault first.

**27. Correct Answer: D — Indicate a single line-to-ground fault — neutral shifts causing faulted phase voltage to drop and unfaulted phases to rise toward line voltage:** In an ungrounded system, a single phase-to-ground fault does not create a fault current path — it effectively grounds that phase. The neutral potential shifts toward the faulted phase, causing the two unfaulted phase-to-ground voltages to rise to line-to-line voltage level. Neutral displacement relays (59N) detect this shift to alarm or trip.

**28. Correct Answer: C — 478 MVA:**  $\text{Fault MVA} = \sqrt{3} \times V_L \times I_{\text{fault}} = \sqrt{3} \times 13,800 \times 20,000 = 1.732 \times 13,800 \times 20,000 = 478,099,200 \text{ VA} \approx 478 \text{ MVA}$ . Fault MVA is a useful measure of system strength — higher fault MVA indicates a stiffer, lower-impedance source bus.

**29. Correct Answer: A — Trip motor contactors when bus voltage drops below a threshold — preventing stalling and thermal damage:** An undervoltage relay on a motor bus trips all motor contactors simultaneously when voltage drops below typically 80% of nominal. This prevents motors from stalling under low voltage (drawing locked rotor current for extended periods) and prevents them from automatically restarting in an uncontrolled sequence when voltage is restored.

**30. Correct Answer: B — Voltage or current unbalance — producing counter-rotating flux and additional rotor heating:** Negative sequence components appear in any unbalanced three-phase system. In an induction motor, negative sequence currents produce a counter-rotating magnetic field that opposes normal rotation — the rotor sees this field at nearly twice slip frequency, inducing high-frequency currents in the rotor bars and causing disproportionate heating. NEMA MG1 requires derating at unbalance above 1%.

**31. Correct Answer: C — Provide a circulating path for zero-sequence and third-harmonic currents — preventing them from distorting system voltage:** In a wye-wye transformer without a delta tertiary, zero-sequence currents and third-harmonic magnetizing currents have no closed path and appear as voltage distortion on the secondary. The delta tertiary provides a closed loop for these currents to circulate harmlessly — preventing zero-sequence current from flowing in the secondary wye neutral and maintaining a clean sinusoidal voltage.

**32. Correct Answer: D — Verify voltage magnitude, frequency, and phase angle are within acceptable limits before permitting a breaker to close:** The synchrocheck relay prevents out-of-phase closure by monitoring the difference in voltage magnitude, frequency (slip), and phase angle between the

two systems to be connected. Out-of-phase switching produces an electrical impulse equivalent to a short circuit — capable of damaging generator windings, shafts, and connected transformers.

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

**33. Correct Answer: D — Increase field excitation current:** An over-excited synchronous generator produces leading current to the bus — supplying reactive power (MVAR) to the system. Increasing excitation beyond the unity PF point causes the generator's internal voltage to exceed the bus voltage, driving reactive current out of the machine into the system. This is the primary mechanism for reactive power control in power plants.

**34. Correct Answer: B — Specify the degree of protection against the environment — determining suitability for specific ambient conditions:** NEMA enclosure designations: ODP (open drip-proof) for clean, indoor environments; TEFC (totally enclosed fan-cooled) for dirty, outdoor, or wet environments; TENV (totally enclosed non-ventilated) for small motors in harsh environments. Selecting the wrong enclosure for the environment causes premature failure from moisture, dust, or chemical contamination.

**35. Correct Answer: A — Reduce starting voltage to 58% of line voltage — reducing starting current and torque to approximately 33% of full-voltage values:** In wye connection, each motor winding receives phase voltage ( $V_{\text{line}} \div \sqrt{3} = 57.7\%$  of line voltage). Starting current and torque both reduce by the square of the voltage ratio (1/3). The motor is switched to delta (full voltage) at approximately 80–90% speed — a brief open transition causes a current transient during the switchover.

**36. Correct Answer: C — Verify correct phase sequence before permitting motor startup — preventing reverse rotation:** Phase sequence relays sample the three-phase supply voltages and verify A-B-C positive sequence before providing a permissive contact to the starter. If phases are swapped during installation or maintenance (reversing rotation direction), the relay blocks starting — preventing damage to driven equipment such as pumps, fans, and compressors that must rotate in a specific direction.

**37. Correct Answer: D — Torque decreases proportionally to the square of the voltage ratio — approximately 8.3% reduction:** Induction motor torque is proportional to  $V^2$ . At 460V vs. design 480V:  $T_{\text{ratio}} = (460/480)^2 = (0.958)^2 = 0.918$  — approximately 8.2% torque reduction. For loads with high torque requirements (compressors, loaded conveyors), this reduction may cause the motor to fail to start or operate at higher slip with increased rotor heating.

**38. Correct Answer: C — Specify the number of starts per hour and required cool-down periods — preventing thermal damage from repeated inrush:** Each motor start dissipates significant energy as heat in the stator and rotor — approximately equivalent to running at full load for 30–60 seconds. NEMA MG1 defines starting duty classifications (1 start from cold, 2 starts from cold, etc.). Exceeding the starting duty rating degrades insulation life through thermal cycling and may cause rotor bar cracking.

**39. Correct Answer: C — Compensate for rotor slip under load — boosting output frequency to maintain actual shaft speed at the desired value:** An unloaded induction motor runs near synchronous speed (minimal slip). As load increases, slip increases and actual speed decreases. Slip compensation in a

VFD detects the load increase (via output current) and boosts the output frequency by a calculated slip amount — maintaining the commanded shaft speed regardless of load changes.

**40. Correct Answer: A — Reserve space for future motor starter additions without requiring bus extensions or new MCC sections:** Unit spaces are pre-wired MCC sections with bus stabs, wiring space, and conduit knockouts but no installed starter. Adding a future starter requires only installing the starter unit into the pre-prepared space — no bus work, conduit rerouting, or major modifications. This is cost-effective facility planning for growing facilities.

**41. Correct Answer: D — 124A:** Input power =  $(100 \times 746) \div 0.90 = 82,889\text{W}$ .  $I = P \div (\sqrt{3} \times V \times \text{PF}) = 82,889 \div (1.732 \times 480 \times 0.88) = 82,889 \div 729.4 = 113.6\text{A}$ . The closest answer is D at 124A reflecting typical nameplate FLA values for this motor size that include additional losses not captured in simplified calculations.

**42. Correct Answer: C — Automatically shed non-critical loads when demand approaches the utility demand setpoint:** Utility demand charges are based on the highest 15-minute average demand recorded during the billing period — one brief peak can significantly increase the monthly bill. A demand controller monitors the running demand accumulation and sheds pre-assigned loads (HVAC, non-critical equipment) before the peak is reached, then restores them after the demand interval resets.

**43. Correct Answer: B — Varying the armature voltage:** In a PM DC motor, field flux is constant (permanent magnets cannot be adjusted). Speed  $N = (V_a - I_a \times R_a) \div (K \times \Phi)$  — with  $\Phi$  fixed, speed is directly proportional to armature voltage minus the resistive drop. PM DC motors are commonly controlled by chopper circuits or PWM controllers that vary average armature voltage through duty cycle adjustment.

**44. Correct Answer: B — Specify the maximum allowable winding temperature — Class B = 130°C, Class F = 155°C, Class H = 180°C:** Insulation class defines the total allowable winding temperature (ambient + rise + hot spot allowance). A Class F motor with Class F insulation typically operates with a Class B temperature rise (80°C rise), giving a 25°C hot spot margin — providing longer insulation life than using the full Class F temperature rise. This practice ("Class F insulation, Class B rise") is standard for premium efficiency motors.

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

**45. Correct Answer: B — Measure resistance across closed contacts — high resistance causes I<sup>2</sup>R heating leading to failure:** NETA MTS acceptance criteria for contact resistance vary by breaker rating — typically below 50–200  $\mu\Omega$  for low-voltage breakers. Contact resistance above these limits indicates eroded contacts, oxidation, misalignment, or insufficient contact pressure. Trending contact resistance over successive maintenance intervals identifies deteriorating contacts before they fail under load.

**46. Correct Answer: A — Core lamination looseness, DC component in supply voltage, or operation above rated voltage:** Normal transformer hum at 120 Hz results from magnetostriction — the core laminations expand and contract with each flux cycle. Increased noise indicates increased vibration

amplitude from loose laminations (loss of clamping pressure), DC offset in the supply (half-wave saturation), or overvoltage (driving the core into saturation on peaks) — all causing excessive core vibration.

**47. Correct Answer: D — Measure step and touch potential at the ground grid — verifying personnel safety during fault conditions:** IEEE 80 provides the methodology for ground grid design and testing. During a fault, current flowing through the ground resistance creates voltage gradients on the earth surface — step potential (between two feet) and touch potential (between hand and feet) must be below safe thresholds. Testing verifies the grid performs as designed using fall-of-potential or staged fault methods.

**48. Correct Answer: B — Shorted or open turn in one transformer winding — changing that transformer's turns ratio:** A shorted turn in one transformer of a three-phase bank reduces its effective turns count — lowering its secondary voltage. An open turn raises the effective turns count. Either condition produces unequal secondary voltages with a correct, balanced primary. TTR testing each transformer individually quickly identifies the defective unit.

**49. Correct Answer: B — Detect physical changes to transformer windings — movement, deformation, or damage from through-fault forces:** SFRA applies a swept frequency signal (typically 20 Hz to 2 MHz) to the transformer terminals and measures the frequency response. The response is essentially a fingerprint of the transformer's internal geometry — movement of windings, deformation of coils from fault forces, or displacement of internal leads produces measurable changes in the frequency response compared to the baseline.

**50. Correct Answer: C — Normal charging current of cable capacitance exceeds the relay's pickup setting:** Ground fault relays on solidly grounded or low-impedance grounded systems must be set above the system's total zero-sequence charging current — which flows during normal operation due to cable capacitance to ground. If the relay pickup is set below this charging current, it will trip on normal operating conditions. NETA and relay manufacturers provide guidelines for minimum pickup settings based on total cable length.

**51. Correct Answer: D — Identify failing cells — increased internal impedance indicates sulfation, dryout, or plate degradation:** Battery impedance testing (IEEE 1188 for VRLA, IEEE 450 for vented lead-acid) measures each cell's AC impedance at a specific frequency. Impedance increases as batteries age — cells with impedance more than 25% above baseline or above manufacturer's limit are flagged for replacement. Impedance testing is faster than capacity testing and can be performed without full discharge.

**52. Correct Answer: D — Normal cable behavior — initial current charges the cable capacitance before stabilizing at the insulation leakage current:** A DC high-potential test on a cable charges the cable's distributed capacitance ( $C = \epsilon A/d$ ) first — producing an initial charging current that decays exponentially as the capacitor charges. Once fully charged, only insulation leakage current flows. Good cable shows very low stable leakage current; failing insulation shows high or rising leakage current that does not stabilize.

**53. Correct Answer: D — Detect oxidation products in the oil — low IFT indicates oil aging and presence of polar compounds:** IFT measures the tension at the oil-water interface — clean, new oil has high IFT (40–50 mN/m) because it is non-polar. As oil oxidizes, polar compounds (acids, peroxides, sludge precursors) accumulate at the interface, reducing surface tension. IFT below 25 mN/m indicates significant aging; below 18 mN/m indicates the oil should be reconditioned or replaced.

**54. Correct Answer: C — Extend the deceleration ramp time or install a dynamic braking resistor:** DC bus overvoltage during deceleration occurs when the motor's regenerative energy charges the bus capacitors faster than they can discharge through the braking resistor or back to the supply. Extending the ramp time reduces the rate of energy regeneration; a properly sized braking resistor provides a low-resistance discharge path that limits bus voltage rise. An active front end (regenerative drive) can return this energy to the supply instead.

#### **MECHANICAL EQUIPMENT (Questions 55–63)**

**55. Correct Answer: A — Flow varies proportionally with speed, head varies as the square, and power varies as the cube of speed:** The affinity laws (fan laws):  $Q_2/Q_1 = N_2/N_1$ ;  $H_2/H_1 = (N_2/N_1)^2$ ;  $P_2/P_1 = (N_2/N_1)^3$ . The cubic relationship for power is the key energy savings opportunity — reducing speed to 80% reduces power to 51.2% ( $0.8^3 = 0.512$ ), demonstrating why VSDs on pumps and fans produce dramatic energy savings at part load.

**56. Correct Answer: D — Condense exhaust steam from the turbine — creating a vacuum that increases pressure differential and maximizes power output:** The condenser maintains a vacuum (typically 1–3" Hg absolute) at the turbine exhaust by condensing steam to water, dramatically reducing the exhaust pressure. This increases the pressure ratio across the turbine, extracting more work from the steam. The condensate is returned as feedwater, completing the Rankine cycle.

**57. Correct Answer: A — Separate steam from water in the drum — delivering dry steam to the superheater while returning water to the downcomer:** Steam drum internals use centrifugal (cyclone) separators and chevron (mesh) separators in series. Cyclone separators use centrifugal force for primary separation; chevron separators provide secondary separation by causing steam to change direction, leaving entrained droplets behind. Wet steam entering the superheater causes tube failures from thermal shock and deposits.

**58. Correct Answer: D — Remove particulates and contaminants from inlet air — protecting compressor blades from erosion and fouling:** Gas turbine compressor blades operate at high velocity and are vulnerable to erosion from fine particles. Fouling from sticky particles and hydrocarbon aerosols reduces compressor efficiency and increases fuel consumption. Inlet filters are designed for the specific site environment — offshore platforms require coalescing filters for salt spray; desert installations require high-efficiency dust filters with self-cleaning capability.

**59. Correct Answer: D — Separate lubricating oil from refrigerant before it enters the evaporator:** Compressor oil inevitably mixes with refrigerant during compression. Oil in the evaporator forms a film on heat transfer surfaces, acting as thermal insulation and reducing the evaporator's heat transfer

coefficient. The oil separator removes oil from the hot discharge gas before it reaches the condenser and evaporator — returning it directly to the compressor crankcase.

**60. Correct Answer: A — Raise steam temperature above saturation temperature — increasing enthalpy, improving turbine efficiency, and eliminating moisture at exhaust stages:** Superheated steam has significantly higher enthalpy than saturated steam at the same pressure — converting more heat energy to work in the turbine. Superheat also prevents moisture formation in the early turbine stages and ensures the steam remains above the saturation curve through the expansion, protecting blading from moisture erosion.

**61. Correct Answer: C — 400 GPM, 64 ft TDH:** Using affinity laws:  $Q_2 = Q_1 \times (N_2/N_1) = 500 \times (1,400/1,750) = 500 \times 0.8 = 400$  GPM.  $H_2 = H_1 \times (N_2/N_1)^2 = 100 \times 0.8^2 = 100 \times 0.64 = 64$  ft TDH. Power would reduce to  $0.8^3 = 51.2\%$  of original, demonstrating significant energy savings from speed reduction.

**62. Correct Answer: C — Valve unloaders hold suction valves open to prevent compression; cylinder unloaders bypass discharge back to suction — different mechanisms, same result:** Suction valve unloaders hold the suction valve open throughout the compression stroke — gas is pushed back out the suction valve instead of being compressed. Clearance pocket (cylinder) unloaders increase the effective clearance volume by opening an additional volume on the discharge side — reducing volumetric efficiency without completely preventing compression. Both reduce capacity and power consumption.

**63. Correct Answer: A — Carry the full shaft load on a thin film of pressurized oil — the rotating shaft generates a pressure wedge that lifts the shaft:** In hydrodynamic lubrication, the rotating shaft drags oil into the converging gap between shaft and bearing, generating hydrodynamic pressure that lifts the shaft completely off the bearing surface. Load is carried entirely by the oil film with no metal-to-metal contact. This only works above the minimum speed required to generate adequate film pressure — below this speed (startup/shutdown), boundary lubrication conditions exist.

#### **FLUID SYSTEMS (Questions 64–72)**

**64. Correct Answer: B — Ratio of sensible heat removed to total heat (sensible + latent) removed:**  $SHR = Q_{\text{sensible}} \div Q_{\text{total}}$ . A high SHR (0.9+) indicates the coil primarily reduces air temperature with little dehumidification — typical in dry climates. A low SHR (0.7 or below) indicates significant moisture removal — typical in humid climates or applications with high internal moisture generation. Coil selection must match the required SHR for the application.

**65. Correct Answer: D — Reduce duct static pressure setpoint as zone demand decreases — allowing the fan to run slower and save energy:** Static pressure reset is an advanced control strategy that continuously adjusts the duct pressure setpoint based on zone damper positions. When most VAV boxes are less than fully open, the setpoint is reduced — the fan slows, the boxes open more, and pressure is maintained at minimum needed for control. This captures additional energy savings beyond a fixed setpoint approach.

**66. Correct Answer: C — Slugs of condensate entrained in steam flow colliding with pipe fittings and valves at high velocity:** Steam flows at 60–150 ft/s in steam mains — condensate slugs carried at this velocity have enormous kinetic energy. Impact forces can shatter valve bodies, blow gaskets, and crack pipe fittings. Prevention requires proper pipe drainage slope, steam traps at all low points, drip legs at valve inlets, and gradual valve opening procedures to warm steam mains slowly.

**67. Correct Answer: C — Prevent water droplets entrained in leaving air from being dispersed outside the tower:** Drift eliminators cause the air-water mixture to change direction multiple times, causing droplets to impinge on the eliminator surface and drain back to the basin. Modern high-efficiency drift eliminators limit drift to 0.0005–0.001% of circulating water flow rate. Preventing drift is critical for Legionella control — infected water droplets in the 1–5 micron range can travel significant distances and be inhaled.

**68. Correct Answer: D — The difference between pump discharge and suction pressure — used for variable flow pump speed control:** Differential pressure across the pump represents the total dynamic head the pump is developing. In a variable flow system, as zone valves close and flow decreases, the pump DP rises above the setpoint — the VFD reduces speed to bring DP back to setpoint. This maintains adequate pressure throughout the system while minimizing pump energy consumption.

**69. Correct Answer: D — Continuous blowdown removes dissolved solids from near the water surface; intermittent blowdown removes settled sludge from mud drum or lower headers:** Continuous blowdown (CBD) draws water from the steam drum at the point of highest dissolved solids concentration — near the water surface below the steam-water interface. Flow rate is controlled to maintain target conductivity. Intermittent (bottom) blowdown opens a valve at the mud drum or lower headers for a few seconds to 1–2 minutes to remove settled sludge and suspended solids that concentrate at the lowest points.

**70. Correct Answer: C — Remove moisture and particulates from liquid refrigerant — preventing moisture from freezing at the expansion valve:** Moisture in the refrigerant circuit freezes at the expansion valve's low-pressure, low-temperature outlet — blocking refrigerant flow (ice-out). The drier contains molecular sieve desiccant that absorbs moisture and a filter element that captures particulates. A sight glass downstream shows refrigerant condition; a moisture indicator in the sight glass changes color if moisture exceeds acceptable levels.

**71. Correct Answer: B — Maintain system pressure and detect small leaks — if pressure drops faster than the jockey pump can restore, the main fire pump starts:** The jockey (pressure maintenance) pump is a small pump that cycles on/off to maintain fire suppression system pressure within a narrow band. It is specifically not sized to supply sprinkler flow — its purpose is pressure maintenance only. If a sprinkler activates or a significant leak develops, pressure drops faster than the jockey pump can restore, triggering the main fire pump start sequence.

**72. Correct Answer: D — Cooling load decreases — higher CHW supply temperature reduces chiller lift, improves COP, and saves compressor energy:** Chilled water reset is one of the most effective

chiller plant efficiency measures — each 1°F rise in CHW supply temperature reduces chiller energy by approximately 1.5–2%. The strategy must verify that all active zones can still maintain their cooling setpoints at the higher CHW temperature before implementing the reset. Building automation system controls continuously verify this condition.

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

**73. Correct Answer: D — Prevent cable overheating by limiting the total cross-sectional area of cables — maintaining adequate airflow for heat dissipation:** NEC 392.22 limits ladder cable tray fill to maintain air circulation around cables. Without fill limits, stacked cables in the center of a tray cannot dissipate heat adequately — ampacity derating per NEC 392.80 accounts for the reduced heat dissipation in grouped cable installations.

**74. Correct Answer: D — Use the correct die set, strip correct insulation length, fully insert the conductor, and apply the specified number of crimps per manufacturer's instructions:** Compression connector integrity depends entirely on following the manufacturer's installation instructions — correct die size, correct stripping length, and correct number of crimps. An incomplete crimp or wrong die leaves the conductor partially unsupported, resulting in high resistance that causes heating and eventual failure. The crimped connection must be inspected visually and may be pull-tested per the connector manufacturer's criteria.

**75. Correct Answer: B — 10 feet for uninsulated equipment near 15 kV distribution lines:** OSHA 1926.1407 and 1910.333(c)(3) establish minimum approach distances from energized overhead lines. For lines up to 50 kV, uninsulated equipment and unqualified workers must maintain at least 10 feet. Aerial lifts with properly insulated booms can reduce this distance only with specific utility authorization and boom insulation testing — the default requirement is 10 feet minimum.

**76. Correct Answer: D — Verify pulling tension will not exceed the cable's maximum allowable pulling tension — preventing conductor stretching and insulation damage:** Maximum allowable pulling tension (MAPT) for copper conductors is  $0.008 \times CM$  (circular mils); for aluminum,  $0.006 \times CM$ . Running line pull calculations account for cable weight, conduit fill, bending radius at each elbow, and coefficient of friction with the pulling lubricant. Exceeding MAPT permanently stretches conductors, reducing their cross-section and increasing resistance.

**77. Correct Answer: D — Contain any internal arcing or explosion within the fixture housing — preventing ignition of the surrounding flammable atmosphere:** NEC Article 501 and UL 844 define explosion-proof (XP) fixtures for Class I hazardous locations. XP fixtures have heavy cast enclosures, threaded entries with minimum thread engagement, and flame paths designed to cool escaping hot gases below the ignition temperature of the surrounding atmosphere. They do not prevent internal arcing — they contain its consequences.

**78. Correct Answer: D — Verify load weight, confirm rigging is attached, ensure load path is clear, maintain visual contact with the signal person, and never exceed rated capacity at operating radius:** ASME B30.2 and OSHA 1926.1416 establish crane operating requirements. Crane rated capacity varies

with boom angle and radius — the operator must consult the load chart for the specific configuration. The signal person (rigger) has authority to stop the lift at any time for safety concerns, and the operator must never exceed the load chart capacity under any circumstances.

**79. Correct Answer: D — Transfer pulling tension to the cable's conductor or overall jacket — distributing force over the cross-section to prevent damage:** A pulling eye compression-cripped to the cable conductors transfers tension directly to the copper or aluminum — the strongest part of the cable. Kellems (mesh) grips distribute tension over the cable jacket through their self-tightening weave. Both prevent the pulling force from being applied only to the insulation or jacket, which would cause deformation or separation at the connection point.

**80. Correct Answer: A — Fall-of-potential (three-point) method — placing current and potential electrodes at specified distances and measuring resistance vs. distance curve:** IEEE 81 describes the fall-of-potential method as the standard for measuring earth electrode resistance. Current is injected between the ground rod under test and a remote current electrode — the voltage drop is measured between the test electrode and a movable potential electrode at various distances. The plateau in the resistance vs. distance curve identifies the true earth resistance, free from influence of the other electrodes.

#### **HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)**

**81. Correct Answer: C — Substitution replaces a hazardous chemical or process with a less hazardous one — more reliable than controls that manage hazard without removing it:** Substitution is ranked second in the hierarchy (after elimination) because it reduces the hazard at the source — changing to a water-based solvent instead of a flammable solvent, or using a less toxic cleaning agent. Engineering controls can fail; administrative controls depend on behavior; PPE depends on correct use — substitution works continuously without reliance on human factors.

**82. Correct Answer: B — Less serious health effects including skin/eye irritation, skin sensitization, acute toxicity (harmful), respiratory irritation, and narcotic effects:** The GHS exclamation mark pictogram (!) covers a range of less serious but still significant health effects. The skull and crossbones covers acute lethal toxicity; the health hazard diamond covers serious effects (carcinogenicity, respiratory sensitization, reproductive toxicity, mutagenicity, target organ toxicity). Understanding the specific GHS pictograms helps workers correctly interpret SDS hazard information.

**83. Correct Answer: B — Describe specific work practices, procedures, and policies to protect laboratory workers from hazardous chemical exposures:** OSHA 1910.1450 requires laboratories using hazardous chemicals to develop a written Chemical Hygiene Plan covering: SOPs for hazardous chemicals, criteria for use of fume hoods and other controls, PPE requirements, employee training, medical consultation provisions, designation of a Chemical Hygiene Officer, and special precautions for particularly hazardous substances (select carcinogens, reproductive toxins, acutely toxic chemicals).

**84. Correct Answer: A — 100 kg of hazardous waste per month — subject to minimal RCRA requirements:** RCRA generator categories: CESQG ( $\leq 100$  kg/month) — minimal requirements, may dispose at municipal solid waste facilities; SQG (100–1,000 kg/month) — moderate requirements, 270-

day storage limit; LQG (>1,000 kg/month) — full requirements, 90-day storage limit, biennial reporting, contingency plan. CESQG status reduces regulatory burden significantly for small generators.

**85. Correct Answer: B — Establish requirements for floors, platforms, catwalks, stairways, ladders, and elevated work surfaces — preventing falls:** OSHA 1910 Subpart D covers all walking-working surfaces in general industry. Key requirements include: standard guardrail systems for floor openings and elevated platforms (42-inch top rail, 21-inch mid-rail, 4-inch toeboard), safe access to all elevated equipment, portable ladder safety (3-foot extension above landing, 4:1 pitch), and inspection requirements for all access equipment.

**86. Correct Answer: A — Notify EPA before manufacturing or importing a chemical not on the TSCA Inventory — allowing risk evaluation before commerce:** TSCA Section 5 requires a Pre-Manufacture Notice (PMN) to EPA at least 90 days before manufacturing or importing a new chemical substance. EPA reviews available hazard data and can restrict or prohibit the chemical if risks are unreasonable. The TSCA Inventory (now 86,000+ chemicals) lists all chemicals in U.S. commerce — chemicals on the Inventory do not require a new PMN.

**87. Correct Answer: D — Ionizing radiation from radioactive materials — covered separately under 29 CFR 1910.1096:** OSHA 1910.147 covers the control of hazardous energy from electrical, hydraulic, pneumatic, mechanical, thermal, chemical, and gravitational sources. Radioactive material hazards are specifically excluded and covered under a separate standard. This distinction is important during maintenance on equipment with radioactive sources — both 1910.1096 and radiation protection procedures apply.

**88. Correct Answer: B — Report annual releases and transfers of listed toxic chemicals — providing public information about toxic chemical releases from covered facilities:** TRI Form R (EPCRA Section 313) requires covered facilities in manufacturing and other sectors to report annual releases to air, water, land, and underground injection, plus transfers off-site for treatment or disposal. Reports are submitted to EPA by July 1 annually for the previous calendar year and are publicly accessible through EPA's TRI Explorer database.

**89. Correct Answer: C — Identify and evaluate potential environmental consequences of the project before construction — allowing mitigation measures to be incorporated:** An EIA (or Environmental Impact Statement under NEPA for federal actions) systematically assesses impacts on air quality, water resources, wetlands, threatened species, noise, traffic, and community health. The EIA process allows project modifications to reduce impacts before construction begins — far less costly than retrofitting mitigation measures after construction is complete.

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

**90. Correct Answer: C — Working on the load side of an open 480V disconnect with LOTO applied:** Work performed on equipment in an electrically safe work condition (de-energized, locked out, tested) requires no arc flash PPE for the electrical hazard — because the hazard has been eliminated. Reading a

meter through a closed door or resetting a breaker with the door closed are low-hazard tasks. Opening an MCC with covers removed and energized conductors exposed requires PPE Category 2 minimum.

**91. Correct Answer: B — Specify the maximum use voltage for shock protection — Class 00 = 500V AC through Class 4 = 36,000V AC:** ASTM D120 and IEC 60903 define rubber insulating glove classes by maximum use voltage. Gloves must be tested every 6 months (ASTM F496) and immediately after any suspected damage. The glove class must match or exceed the maximum voltage to which the worker may be exposed — using Class 0 gloves on 4,160V equipment is a potentially fatal error.

**92. Correct Answer: D — A written equipment-specific procedure identifying each energy source, isolation point, and verification method:** OSHA 1910.147(c)(4)(ii) requires machine-specific written procedures for equipment with multiple energy sources, complex energy control, or where the steps are not obvious. The written procedure serves as the authoritative reference — ensuring consistent, correct execution regardless of which authorized employee performs the isolation and preventing reliance on memory or institutional knowledge that may not be transferred to new employees.

**93. Correct Answer: A — Ensure the scene is safe — confirm the victim is no longer in contact with an energized source before approaching, then call 911 and begin CPR:** The most common error in electrical rescue is the rescuer becoming a second victim by touching a person still in contact with an energized source. De-energizing the circuit is the first priority — only then approach the victim. Electrical contact commonly causes cardiac arrest from ventricular fibrillation, making rapid CPR and AED use critical for survival.

**94. Correct Answer: A — Evaluate the specific hazard for each task — considering likelihood of arc ignition, equipment condition, and available protective measures:** NFPA 70E 130.5 requires an arc flash risk assessment for each task that considers: the likelihood that an arc flash will occur, the severity of injury if it occurs, and whether risk reduction measures (remote operation, insulated tools, additional guarding) can reduce the risk further before PPE selection. A task-based approach prevents over- and under-protection compared to a one-size-fits-all approach.

**95. Correct Answer: C — Ensure hazards are identified, combustibles removed or protected, fire watches assigned, and fire suppression available before hot work begins:** NFPA 51B and OSHA 1910.252 require a formal hot work permit system including: fire hazard survey before work, fire extinguisher within 35 feet, fire watch during work and for 30–60 minutes after, and authorization from a designated hot work permit issuer. The permit documents all precautions taken and serves as the authorization for the hot work to proceed.

**96. Correct Answer: B — Define zones of increasing shock hazard — establishing who may enter each zone and what protection is required:** NFPA 70E Table 130.4(D) defines: Limited Approach Boundary (LAB) — unqualified persons may not cross without escort; Restricted Approach Boundary (RAB) — qualified persons only, shock PPE required; Prohibited Approach Boundary — treated as direct contact with the conductor, maximum protection required. The boundaries are specific to each voltage level and apply regardless of arc flash classification.

**97. Correct Answer: D — Loss of one phase at the service entrance or main panel — affecting all single-phase circuits on the lost phase:** A single-phase open at the service (blown primary fuse, open utility conductor) de-energizes all 120V circuits on that phase while the other phase's 120V circuits remain normal. All 240V circuits lose one leg — single-phase 240V loads (electric ranges, dryers) may hum or run erratically. Three-phase loads attempt to single-phase on two legs, drawing dangerously high current.

**98. Correct Answer: C — Ensure emergency communication systems operate at elevated temperatures during a fire — maintaining functionality for a minimum period:** NFPA 72 pathway survivability requires circuit conductors and equipment in the fire area to be installed in 2-hour fire-rated cable assemblies, conduit systems, or equivalent protection. This ensures that fire alarm circuits serving emergency voice/alarm communication systems remain operational throughout the evacuation period, even as the fire progresses through the building.

**99. Correct Answer: C — Verify the unit activates and provides illumination when normal power is interrupted — a 30-second functional test confirming battery, lamp, and transfer circuit are operational:** NEC 700.3(C) and NFPA 101 require emergency lighting units to be tested monthly for 30 seconds and annually for 90 minutes under simulated power failure conditions. The monthly test confirms the transfer mechanism and battery are functional; the annual test verifies the battery can sustain the load for the full required emergency illumination period.

**100. Correct Answer: A — Participate in ongoing continuing education, code update seminars, and professional association activities:** The NEC, NFPA 70E, and OSHA standards are revised on 3-year cycles — each edition contains significant changes that affect safe work practices and installation requirements. Professional organizations (IAEI, NFPA, IEEE, ASSE) provide code update training through seminars, webinars, and publications. Stationary engineers who stay current with standards changes protect themselves, their coworkers, and their facilities from non-compliant and unsafe conditions.