

PRACTICE EXAM 15: STATIONARY ENGINEER (ELECTRIC) SIMULATION — 100 QUESTIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. A 120V circuit has a 20Ω resistor and 15Ω capacitive reactance in series. The impedance is?

- A. 35Ω
- B. 20Ω
- C. 25Ω
- D. 5Ω

2. In a purely inductive AC circuit, current?

- A. Lags voltage by 90°
- B. Leads voltage by 90°
- C. Is in phase with voltage
- D. Leads voltage by 45°

3. The power consumed by a 10Ω resistor carrying 4A is?

- A. 160W
- B. 40W

C. 400W

D. 80W

4. In a balanced three-phase delta circuit, the relationship between line current and phase current is?

A. Line current equals phase current

B. Line current equals phase current divided by $\sqrt{3}$

C. Line current equals phase current multiplied by $\sqrt{3}$

D. Line current equals phase current multiplied by 3

5. The time constant of a series RC circuit with $R = 50\text{k}\Omega$ and $C = 20\mu\text{F}$ is?

A. 2.5 seconds

B. 0.4 seconds

C. 1.0 second

D. 0.1 second

6. A transformer primary has 500 turns connected to 240V. To obtain 48V secondary, the number of secondary turns required is?

A. 2,500

B. 240

C. 100

D. 50

7. The purpose of a snubber circuit across a relay coil is to?

- A. Increase relay coil inductance
- B. Suppress the voltage spike when the coil is de-energized
- C. Reduce relay coil current during operation
- D. Improve relay contact life by increasing contact pressure

8. In a three-phase wye system, the line voltage is 480V. The phase voltage is approximately?

- A. 480V
- B. 831V
- C. 277V
- D. 240V

9. The term "power factor" in an AC circuit is defined as?

- A. Apparent power divided by real power
- B. Real power divided by apparent power
- C. Reactive power divided by apparent power
- D. Real power divided by reactive power

10. A 5kVA, 480/120V transformer. The primary full-load current is?

- A. 41.7A
- B. 10.4A
- C. 5A
- D. 24A

11. In a DC circuit, a 100Ω and 200Ω resistor are connected in parallel. The equivalent resistance is?

- A. 66.7Ω
- B. 300Ω
- C. 150Ω
- D. 100Ω

12. The unit of magnetic flux density is the?

- A. Weber
- B. Henry
- C. Faraday
- D. Tesla

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

13. Per NEC 210.52, the maximum spacing between receptacle outlets in a dwelling unit living area is?

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

14. The minimum cover requirement for direct-buried THWN conductors in rigid PVC conduit under a residential driveway is?

- A. 24 inches

- B. 18 inches
- C. 12 inches
- D. 6 inches

15. The maximum rating for a dual-element time-delay fuse protecting a single-phase motor with 20A FLA per NEC 430.52 is?

- A. 20A
- B. 25A
- C. 150A
- D. 175% of FLA = 35A

16. Under NEC 250.122, the equipment grounding conductor size is based on?

- A. The load current of the circuit
- B. The conductor ampacity of the phase conductors
- C. The available fault current at the panel
- D. The rating of the overcurrent protective device for the circuit

17. A 277V fluorescent lighting circuit requires a minimum conductor size to limit voltage drop to 3% over 150 feet carrying 15A. The required minimum AWG is?

- A. 12 AWG
- B. 10 AWG
- C. 8 AWG
- D. Requires calculation — 10 AWG based on $VD = (2 \times K \times I \times L) \div CM$

18. Type THHN conductor insulation is rated for?

- A. 60°C dry locations
- B. 75°C wet locations
- C. 90°C wet and dry locations
- D. 90°C dry, 75°C wet locations

19. The purpose of a listed combination arc fault circuit interrupter (AFCI) is to?

- A. Provide ground fault protection only
- B. Detect both series and parallel arc faults in a branch circuit
- C. Replace GFCI protection in wet locations
- D. Protect only 240V circuits from arcing faults

20. The NEC requires that all conductors of a circuit occupy the same raceway or cable to?

- A. Simplify circuit identification during maintenance
- B. Prevent inductive heating of metal conduit from unbalanced magnetic fields when conductors are separated
- C. Reduce voltage drop in long circuit runs
- D. Comply with color coding requirements for multi-wire circuits

21. Per NEC 430.52, the maximum inverse time circuit breaker size for a 3-phase motor with 65A FLA is?

- A. 65A
- B. 100A
- C. 162.5A — 250% of FLA rounded to next standard size

D. 200A

22. The purpose of a "listed" panelboard is that it has been?

- A. Approved by the local AHJ for a specific installation
- B. Manufactured in a UL-listed facility
- C. Tested and found to meet applicable UL and NEC product standards by an NRTL
- D. Inspected and accepted by a licensed electrical inspector

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

23. The purpose of a differential relay (ANSI 87T) on a power transformer is to?

- A. Compare currents entering and leaving the transformer — operating to trip if the difference exceeds a set threshold, indicating an internal fault
- B. Protect the transformer from sustained overload conditions
- C. Detect turn-to-turn faults by measuring transformer impedance
- D. Monitor transformer oil temperature and trip on overtemperature

24. The term "X/R ratio" in short circuit analysis refers to?

- A. The ratio of transformer primary to secondary impedance
- B. The ratio of line reactance to transformer resistance
- C. The ratio of system reactance to resistance at the fault point — determining the DC offset and asymmetry of the fault current
- D. The ratio of fault current to load current at the bus

25. The purpose of an underfrequency load shedding (UFLS) relay is to?

- A. Automatically disconnect pre-selected loads when system frequency drops below a threshold — preventing total system collapse by reducing load to match available generation
- B. Trip generators when system frequency drops below rated speed
- C. Reconnect loads after frequency is restored following a disturbance
- D. Protect motors from damage caused by low-frequency operation

26. A 500 kVA, 13,800/480V transformer has an impedance of 5.75%. The available fault current at the secondary terminals is approximately?

- A. 500A
- B. 1,000A
- C. 14,935A
- D. 12,048A

27. The purpose of a Buchholz relay on an oil-filled transformer is to?

- A. Monitor transformer loading and provide thermal overload protection
- B. Detect gas accumulation and oil surge caused by internal faults — providing alarm and trip functions before catastrophic failure
- C. Protect the transformer from external fault currents
- D. Control the tap changer position for voltage regulation

28. In a medium-voltage switchgear lineup, the purpose of primary and secondary injection testing is to?

- A. Verify switchgear bus bar continuity under load conditions
- B. Test the switchgear's arc flash energy level at operating current

C. Calibrate the switchgear's metering CTs and PTs

D. Verify protective relay operation — primary injection tests the complete circuit including CTs; secondary injection tests the relay alone

29. The purpose of "zone selective interlocking" (ZSI) in a low-voltage switchgear system is to?

A. Prevent multiple breakers from closing simultaneously during bus restoration

B. Coordinate breaker timing using fiber optic communication between panels

C. Allow remote racking of draw-out breakers from outside the arc flash boundary

D. Allow the breaker nearest the fault to trip instantaneously while the upstream breaker uses a time delay — reducing arc flash energy compared to non-ZSI systems

30. The IEEE device number for an overvoltage relay is?

A. 27

B. 50

C. 81

D. 59

31. The purpose of a current transformer's "burden" rating is to?

A. Specify the maximum primary current the CT can measure

B. Define the CT's accuracy class for revenue metering

C. Specify the maximum impedance of the secondary circuit — exceeding the burden causes the CT to saturate, producing inaccurate secondary current

D. Define the CT's continuous thermal current rating

32. In a switchgear bus arrangement, a "single bus" configuration's primary disadvantage is?

- A. Any bus fault or maintenance on the bus requires all connected circuits to be de-energized simultaneously
- B. It requires more circuit breakers than other bus arrangements
- C. It cannot accommodate bus tie breakers
- D. It provides no protection against single bus faults

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

33. A synchronous generator operating in parallel with the utility must be synchronized before closing the tie breaker. The synchronization requirements include?

- A. Equal voltage magnitude only
- B. Equal frequency only
- C. Equal voltage and frequency only
- D. Equal voltage magnitude, frequency, phase angle, and phase sequence

34. The purpose of a motor's "locked rotor current" (LRC) rating is to?

- A. Define the maximum continuous current the motor can carry
- B. Specify the motor's starting torque at zero speed
- C. Indicate the current drawn at standstill when rated voltage is applied — used to size branch circuit protection and assess starting voltage drop
- D. Define the current at which the thermal overload relay trips

35. In a VFD, the purpose of a DC bus choke (reactor) is to?

- A. Filter harmonics from the VFD output to the motor
- B. Limit motor cable charging current during IGBT switching
- C. Reduce harmonic currents drawn from the supply and limit DC bus ripple
- D. Protect the IGBT modules from overvoltage during regeneration

36. The purpose of a motor's "service factor" nameplate data when sizing an overload relay is to?

- A. Allow the overload relay to be set 15% above the SF-adjusted current
- B. Determine the motor's locked rotor kVA for branch circuit fuse sizing
- C. Allow NEC 430.32 to permit relay sizing at 125% of FLA for motors with $SF \geq 1.15$
- D. Define the maximum allowable overload relay trip time

37. A three-phase, 480V, 25 HP motor has an efficiency of 92% at full load. The full-load input kVA at 0.88 PF is approximately?

- A. 23.8 kVA
- B. 21.0 kVA
- C. 18.5 kVA
- D. 27.1 kVA

38. The purpose of a dynamic braking resistor in a VFD system is to?

- A. Dissipate regenerative energy from the motor as heat during deceleration — preventing DC bus overvoltage when an active front end is not used
- B. Limit motor starting current during acceleration
- C. Protect the IGBT modules from short circuit during braking
- D. Maintain constant motor speed during load changes

39. An induction motor's slip at full load is 3%. If synchronous speed is 1,800 RPM, the full-load rotor speed is?

- A. 1,854 RPM
- B. 1,800 RPM
- C. 1,746 RPM
- D. 1,746 RPM — $N_r = N_s \times (1 - s) = 1,800 \times 0.97 = 1,746$ RPM

40. The purpose of a motor control center's (MCC) "pull-out" or "draw-out" design is to?

- A. Allow motor starters to be replaced while the MCC bus is energized — only the bucket is isolated, not the entire MCC
- B. Enable remote racking of starters via robotics
- C. Reduce MCC footprint by stacking starters vertically
- D. Allow individual motor starter buckets to be de-energized, isolated, and removed for maintenance without de-energizing the entire MCC bus

41. In a reduced-voltage autotransformer starter, the motor is initially connected to what percentage of line voltage?

- A. 100%
- B. 80%
- C. 50%, 65%, or 80% — selected by tap position on the autotransformer
- D. 33%

42. The purpose of a phase failure relay in a motor circuit is to?

- A. Detect loss of one or more supply phases and trip the motor before single-phasing causes winding damage

- B. Monitor motor winding temperature directly
- C. Detect motor shaft speed during starting
- D. Provide backup overload protection if the main overload relay fails

43. A 480V, 3-phase motor starter uses a 120V control transformer. The primary fuse on the control transformer should be sized at?

- A. 125% of the transformer's rated primary current
- B. 200% of motor FLA
- C. Sized per NEC 430.72 for control circuit protection — typically not more than 500% of the transformer's rated primary current for small control transformers
- D. Equal to the branch circuit fuse rating

44. The purpose of a "memory" function in a digital motor protection relay (MPR) is to?

- A. Store the motor's nameplate data for automatic relay configuration
- B. Retain the thermal model state during power outages — preserving the accumulated thermal capacity used so the relay correctly prevents immediate restart of a hot motor after a power failure
- C. Log all motor starts and stops for maintenance scheduling
- D. Store pre-set relay configurations for multiple motor types

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

45. The purpose of a step voltage test during cable insulation testing is to?

- A. Apply increasing voltage levels in steps, monitoring leakage current at each step — a disproportionate increase in leakage current at a particular step indicates insulation weakness at that stress level
- B. Test the cable's conductor resistance at different temperature steps

- C. Verify cable ampacity at progressively higher current levels
- D. Identify the cable's resonant frequency under AC voltage stress

46. When troubleshooting a tripped thermal overload relay, the first step before resetting and restarting is to?

- A. Replace the overload relay heater element
- B. Investigate and correct the cause of the overload before resetting — mechanical overload, high ambient temperature, voltage unbalance, or blocked ventilation
- C. Increase the overload relay trip setting to prevent nuisance tripping
- D. Verify the motor's insulation resistance before restart

47. The purpose of a partial discharge (PD) test on medium-voltage motor stator windings is to?

- A. Measure the motor winding resistance at operating temperature
- B. Verify the motor's locked rotor current matches the nameplate
- C. Detect insulation deterioration — PD activity in the stator slots indicates insulation voids, delamination, or contamination that accelerates insulation failure
- D. Test the effectiveness of the motor's shaft grounding ring

48. A power quality analyzer installed on a 480V bus records a total harmonic distortion (THD) of 18% voltage. This level indicates?

- A. Normal harmonic levels within IEEE 519 limits for most systems
- B. Minor harmonic distortion requiring only periodic monitoring
- C. Borderline harmonic levels requiring filter evaluation
- D. Elevated harmonic distortion exceeding IEEE 519 limits of 5% THD-V for systems below 1kV — potentially causing equipment overheating, nuisance tripping, and metering errors

49. The purpose of a transformer turns ratio (TTR) test performed after a transformer has been in service is to?

- A. Verify the transformer's impedance has not changed due to aging
- B. Measure core loss changes from oil degradation
- C. Confirm the load tap changer (LTC) operates correctly at each tap position
- D. Detect shorted turns or winding damage by comparing the measured turns ratio against the nameplate ratio at each tap position

50. When performing insulation resistance testing on a 4,160V motor, the recommended test voltage per IEEE 43 is?

- A. 500V DC
- B. 2,500V DC
- C. 1,000V DC
- D. 5,000V DC

51. A megohmmeter reading on a motor drops from 500 M Ω (previous test) to 15 M Ω (current test) with the same test conditions. This trend indicates?

- A. Significant insulation deterioration — a large drop in IR between tests suggests moisture ingress, contamination, or insulation aging that warrants further investigation before returning the motor to service
- B. Normal variation within acceptable test tolerance
- C. The motor requires rewinding immediately
- D. The test voltage was too high and damaged the insulation

52. The purpose of a battery discharge capacity test on a UPS or emergency lighting battery bank is to?

- A. Verify the battery bank can deliver its rated capacity (Ah) to the design end voltage — confirming adequate runtime for the connected load under actual discharge conditions
- B. Measure individual cell impedance values
- C. Test the battery charger's output voltage regulation
- D. Verify the battery's short circuit current capability

53. An oscilloscope shows a flat-topped (clipped) voltage waveform on a 480V bus. This indicates?

- A. Transformer core saturation or capacitor bank resonance — flat-topping is caused by voltage clamping at peak voltage by capacitors or by saturated transformer cores drawing high magnetizing current
- B. An open circuit in the voltage measurement leads
- C. Normal waveform distortion from non-linear loads
- D. A loose connection in the bus bar system

54. The purpose of a "hot collar" test on a suspension insulator string is to?

- A. Measure the string's mechanical tension under load
- B. Test the string's resistance to flashover under lightning impulse
- C. Identify cracked or defective discs by measuring voltage distribution across the string
- D. Verify the corona ring is properly positioned on the string

MECHANICAL EQUIPMENT (Questions 55–63)

55. The purpose of a centrifugal pump's minimum flow bypass line is to?

- A. Provide an alternate flow path when the discharge valve is closed for maintenance
- B. Protect the pump from overheating and cavitation at very low or zero flow — recirculating minimum required flow back to the suction source

- C. Maintain constant system pressure during variable flow operation
- D. Allow the pump to operate at reduced speed without VFD

56. In a reciprocating compressor, the clearance volume affects?

- A. Maximum discharge pressure only
- B. Oil consumption during operation
- C. Volumetric efficiency — larger clearance volume increases re-expansion of residual gas, reducing the effective displacement and volumetric efficiency
- D. Rod packing life and seal performance

57. The purpose of a boiler's safety valve is to?

- A. Control normal operating pressure by modulating steam flow
- B. Open automatically when boiler pressure exceeds the maximum allowable working pressure (MAWP) — preventing catastrophic pressure vessel failure
- C. Provide a controlled pressure letdown for plant startup
- D. Protect the boiler feedwater pump from overpressure

58. A gear pump's output flow is primarily determined by?

- A. Discharge pressure and fluid viscosity
- B. Inlet fluid temperature only
- C. Rotational speed and displacement per revolution — gear pumps are positive displacement devices; flow is nearly proportional to speed regardless of pressure
- D. The pressure difference between suction and discharge

59. The purpose of a steam turbine's turning gear is to?

- A. Control turbine speed during normal operation
- B. Engage the governor for overspeed protection during startup
- C. Allow manual speed adjustment during synchronization
- D. Slowly rotate the turbine rotor during cooling down after shutdown — preventing thermal bowing of the rotor from uneven heat distribution

60. In a hydraulic system, a pressure relief valve set at 3,000 PSI that continuously passes fluid to the reservoir indicates?

- A. Normal operation — relief valves always pass a small amount of fluid
- B. The system pressure is correctly regulated at 3,000 PSI
- C. The system pressure has reached or exceeded 3,000 PSI — either the load requires more than 3,000 PSI or the relief valve setpoint is too low for the application
- D. The relief valve has failed closed

61. The purpose of an oil mist lubrication system on large rotating equipment is to?

- A. Deliver a precisely metered mist of oil particles to bearings continuously — providing reliable lubrication with lower oil consumption and cooler bearing temperatures than flood lubrication
- B. Clean and filter the lube oil before it reaches the bearings
- C. Cool the bearing housing using oil as a heat transfer medium
- D. Detect bearing wear particles before catastrophic failure

62. A centrifugal pump that produces cavitation noise (cracking or popping sounds) should be investigated for?

- A. Insufficient NPSH available — the fluid is vaporizing at the impeller inlet due to low suction pressure or high fluid temperature, causing vapor bubble collapse and impeller erosion
- B. Excessive bearing preload causing mechanical noise
- C. Motor misalignment transmitted through the coupling
- D. Worn impeller wear rings allowing excessive internal recirculation

63. The purpose of a lube oil pressure switch on a large motor or compressor is to?

- A. Prevent startup or trip the machine if lube oil pressure drops below the minimum required — protecting bearings from running without adequate oil film
- B. Control the lube oil pump motor speed
- C. Monitor oil temperature as a proxy for oil pressure
- D. Initiate automatic oil changes based on operating hours

FLUID SYSTEMS (Questions 64–72)

64. The term "superheat" in a refrigeration system refers to the temperature of refrigerant vapor?

- A. At the condenser outlet
- B. At the compressor discharge before desuperheating
- C. At the expansion valve inlet
- D. Above its saturation temperature at the current pressure — measured at the evaporator outlet to confirm all liquid has evaporated before the compressor

65. The purpose of a condenser water bypass valve in a chiller plant is to?

- A. Maintain minimum condenser water temperature entering the chiller during cold weather — preventing refrigerant condensing pressure from dropping too low

- B. Regulate condenser water flow during chiller startup
- C. Prevent condenser water from freezing in the cooling tower basin
- D. Balance flow between multiple chillers on a common condenser water header

66. In a steam system, the purpose of a flash tank is to?

- A. Store emergency feedwater for boiler low-water conditions
- B. Separate steam from condensate in the return main
- C. Remove non-condensable gases from the steam supply
- D. Allow high-pressure condensate to flash to low-pressure steam — recovering useful energy that would otherwise be wasted through a trap to the drain

67. The purpose of a variable speed drive on a cooling tower fan is to?

- A. Prevent fan motor overload during high-humidity conditions
- B. Provide soft starting to reduce mechanical stress on the fan drive
- C. Modulate tower capacity by varying fan speed — reducing energy consumption at part load and allowing precise leaving water temperature control
- D. Limit fan speed to prevent ice formation on the fill during cold weather

68. In a compressed air system, a pressure dew point of -40°F means?

- A. Moisture will not condense in the distribution system above -40°F ambient temperature — appropriate for outdoor or cold environment air systems
- B. The compressor inlet air temperature is -40°F
- C. The refrigerated dryer is operating at -40°F refrigerant temperature
- D. The air must be heated to -40°F before use in instrument air applications

69. The purpose of a boiler blowdown heat exchanger is to?

- A. Heat makeup water using steam extracted from the boiler
- B. Recover heat from hot blowdown water before it is discharged — preheating makeup water and reducing energy waste and thermal pollution of the drain
- C. Cool boiler feedwater to prevent feedpump cavitation
- D. Preheat combustion air using boiler blowdown energy

70. In a chilled water plant, the purpose of a chiller sequencing control is to?

- A. Start and stop chillers based on system cooling load — staging chillers on and off to keep operating chillers near their most efficient load point rather than running all chillers at low load
- B. Prevent more than one chiller from starting simultaneously
- C. Synchronize chiller compressor speed with cooling tower fan speed
- D. Balance refrigerant charge between multiple chillers

71. The purpose of a makeup air unit (MAU) in a building mechanical system is to?

- A. Recirculate return air to dilute indoor air contaminants
- B. Provide supplemental cooling to server rooms and data centers
- C. Condition and deliver 100% outdoor air to the building — replacing air exhausted by ventilation systems and maintaining positive building pressure to prevent infiltration
- D. Heat only outdoor air for perimeter heating applications

72. In a hydronic heating system, the purpose of an expansion tank is to?

- A. Store reserve water volume for makeup during system leaks

- B. Absorb the volume change of water as it heats and cools — maintaining system pressure within acceptable limits and preventing relief valve operation during normal thermal expansion
- C. Provide a point for system air elimination
- D. Buffer heating capacity during peak load periods

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

73. The purpose of a fish tape (snake) in electrical work is to?

- A. Pull wire through existing conduit runs
- B. Thread through a conduit to attach and pull conductors — navigating bends and obstructions in the raceway
- C. Test for energized conductors before opening a panel
- D. Bond conduit sections during installation

74. When making up a wire rope clip (U-bolt clip) on a wire rope, the correct installation requires?

- A. The U-bolt saddle on the live (load-bearing) end and the clip spaced one rope diameter apart — "never saddle a dead horse"
- B. The U-bolt on the dead end and saddle on the live end spaced 6 rope diameters apart
- C. Both clips oriented in the same direction regardless of which end is live
- D. Minimum 2 clips for all rope diameters with 3 rope diameter spacing

75. When installing PVC conduit in an outdoor location subject to UV exposure, the correct material specification is?

- A. Schedule 40 PVC — UV resistant for all outdoor applications
- B. Schedule 80 PVC — thicker wall provides UV protection

C. Schedule 40 or 80 PVC listed for sunlight exposure — standard PVC degrades without UV-stabilizing additives; only sunlight-resistant listed PVC conduit is permitted outdoors above grade

D. PVC conduit is not permitted outdoors — RMC or IMC required

76. The purpose of a continuity tester before energizing a newly installed conduit system is to?

A. Verify the insulation resistance of the installed conductors

B. Verify that all conductors are properly connected end-to-end and that no open circuits, crossed conductors, or missing connections exist before energization

C. Test the conduit system's grounding continuity

D. Identify conductor AWG size by measuring resistance per foot

77. The correct way to inspect a manila fiber rope before use is to?

A. Check it visually only — internal condition cannot be assessed without destructive testing

B. Untwist the strands to inspect the interior fibers for dryness, discoloration, brittleness, or internal mildew — indicating deterioration that reduces the rope's strength below its rated WLL

C. Load test to 50% of breaking strength before each use

D. Check only the end terminations for fraying and cuts

78. The purpose of a load cell in a rigging operation is to?

A. Calculate the center of gravity of the lifted load automatically

B. Verify the rigging hardware WLL before the lift

C. Measure the actual load on a hoist or crane hook — allowing the operator to verify the load is within the crane's rated capacity and identify unexpected weight variations

D. Monitor sling angle to ensure compliance with rated WLL

79. When connecting aluminum conductors to equipment terminals, the correct preparation includes?

- A. Applying anti-oxidant compound and using terminals listed for aluminum conductors — aluminum's oxide layer and thermal expansion characteristics require specific termination practices to prevent high-resistance connections
- B. Tinning the conductor end with solder before insertion
- C. Wire-brushing the conductor and immediately inserting into a standard copper-rated terminal — no compound required
- D. Using mechanical compression splices only — set screw terminals are not permitted for aluminum conductors

80. The purpose of a knockout punch set in electrical work is to?

- A. Create clean, correctly sized holes in enclosure and panel knockouts for conduit hubs and fittings — producing round, burr-free holes that accept listed fittings properly
- B. Remove concentric knockouts from panel boxes
- C. Punch holes in concrete for anchor bolt installation
- D. Cut threaded openings in metal enclosures for conduit entry

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. The OSHA permissible exposure limit (PEL) for noise is?

- A. 85 dBA as an 8-hour TWA
- B. 90 dBA as a 4-hour TWA
- C. 85 dBA as a ceiling value
- D. 90 dBA as an 8-hour TWA — with a 5 dB exchange rate; OSHA requires a hearing conservation program when noise exceeds 85 dBA TWA

82. Under EPA 40 CFR Part 68 (RMP), the worst-case release scenario for a toxic chemical assumes?

- A. Average meteorological conditions and 50% release of inventory
- B. Instantaneous release of the largest vessel quantity under most stable atmospheric conditions with no active mitigation
- C. Release during normal transfer operations with wind speed of 3 m/s
- D. Instantaneous release of the largest single vessel or pipe segment with no active mitigation under worst-case meteorological conditions (F stability, 1.5 m/s wind)

83. The purpose of a Safety Data Sheet's Section 14 (Transport Information) is to?

- A. Provide UN number, proper shipping name, hazard class, and packing group — required for shipping the chemical by road, rail, air, or sea in compliance with DOT and IATA regulations
- B. List emergency response procedures for transportation accidents
- C. Specify packaging requirements for retail sale
- D. Identify the chemical's reactivity with other transported materials

84. Under RCRA, a "satellite accumulation area" (SAA) allows a generator to?

- A. Store hazardous waste at any location on the facility
- B. Accumulate up to 55 gallons of hazardous waste (or 1 quart of acutely hazardous waste) at the point of generation without a storage time limit — provided it remains under the control of the operator generating the waste
- C. Store unlimited quantities of hazardous waste for up to 90 days
- D. Dispose of small quantities of hazardous waste directly to the sanitary sewer

85. The purpose of the OSHA 300 Log is to?

- A. Track all first aid incidents at the facility

B. Record work-related injuries and illnesses that meet OSHA recordkeeping criteria — maintained for 5 years and made available to employees and OSHA upon request

C. Document near-miss incidents for safety analysis

D. Record all workers' compensation claims regardless of OSHA recordability

86. Under the Clean Air Act Title V, a major source permit is required for facilities that emit?

A. Any regulated air pollutant above 1 ton per year

B. 100 tons per year or more of any regulated air pollutant — or 10 tons of any single HAP or 25 tons of combined HAPs (lower thresholds apply in non-attainment areas)

C. 250 tons per year of criteria pollutants only

D. Any amount of listed hazardous air pollutants (HAPs)

87. The primary purpose of a facility's Pollution Prevention (P2) program under EPA guidance is to?

A. Reduce or eliminate the generation of pollutants at the source — before they require treatment, control, or disposal

B. Treat wastewater to meet NPDES permit limits

C. Offset facility emissions through carbon credit purchases

D. Comply with RCRA hazardous waste reduction requirements only

88. Under OSHA 1910.1025, the action level for inorganic lead exposure is?

A. 50 $\mu\text{g}/\text{m}^3$ as an 8-hour TWA

B. 10 $\mu\text{g}/\text{m}^3$ as a ceiling value

C. 200 $\mu\text{g}/\text{m}^3$ as a short-term exposure limit

D. 30 $\mu\text{g}/\text{m}^3$ as an 8-hour TWA — triggering air monitoring, medical surveillance, and training requirements

89. The purpose of an environmental aspect and impact register in an ISO 14001 environmental management system is to?

- A. Document facility environmental permits and compliance status
- B. Satisfy EPA reporting requirements for toxic release inventory
- C. Identify the facility's activities that can affect the environment and evaluate their significance — forming the basis for setting environmental objectives and operational controls
- D. Record environmental incidents and spills for regulatory reporting

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

90. Under NFPA 70E, the restricted approach boundary for a 480V exposed energized conductor is?

- A. 42 inches
- B. 12 inches — only qualified persons may cross this boundary, and additional shock protection (rubber insulating gloves) is required
- C. 6 inches
- D. 3 feet 6 inches

91. The purpose of an arc flash label on electrical equipment per NEC 110.16 and NFPA 70E is to?

- A. Replace the need for an arc flash risk assessment for standard maintenance tasks
- B. Satisfy the equipment manufacturer's warranty requirements
- C. Warn qualified workers of arc flash hazard — providing incident energy or PPE category, working distance, and required PPE before the equipment is approached or opened
- D. Serve as the sole PPE selection method for all energized work tasks

92. Under OSHA 1910.147, "lockout" differs from "tagout" in that lockout?

- A. Requires more complex administrative procedures than tagout
- B. Is required only for electrical energy sources
- C. Physically prevents the energy isolating device from being operated — providing positive isolation that cannot be defeated by mistake, unlike a tag which is only a warning and can be removed
- D. Requires a longer verification period before work begins

93. The purpose of a rescue plan required for permit-required confined space entry is to?

- A. Describe the procedure for calling 911 only
- B. List emergency contact numbers for the facility safety department
- C. Specify how an incapacitated entrant will be retrieved from the space without requiring rescuers to enter — using mechanical retrieval equipment (tripod and winch) wherever feasible, with trained attendant rescue as backup
- D. Document the medical qualifications of the entry supervisor

94. The correct sequence for donning electrical PPE before energized work is?

- A. Arc-rated clothing first, then rubber insulating gloves, then face shield and hard hat — ensuring the highest-risk items (hands and face) are protected last to prevent contamination of the insulating surfaces before approaching the work
- B. Hard hat first, then arc-rated clothing, then gloves
- C. Gloves first, then clothing, then face shield
- D. Face shield first, then gloves, then arc-rated clothing

95. The purpose of NFPA 72's "mass notification system" (MNS) requirement in certain occupancies is to?

- A. Replace the traditional fire alarm system in large facilities
- B. Deliver intelligible voice instructions to building occupants during emergencies — providing specific evacuation or shelter-in-place instructions beyond the capability of standard horn/strobe notification
- C. Provide backup communication if the fire alarm system fails
- D. Satisfy ADA requirements for hearing-impaired occupants only

96. When a stationary engineer observes a co-worker receiving an electrical shock and the worker is still in contact with the energized source, the correct first response is to?

- A. Grab the victim and pull them away from the source immediately
- B. Call 911 before taking any other action
- C. De-energize the circuit immediately if the disconnect is within reach — only then approach and assess the victim; do not touch the victim while they are still in contact with an energized source
- D. Use a rubber mat to insulate yourself before touching the victim

97. The purpose of OSHA's "hierarchy of controls" as applied to arc flash hazard mitigation is to?

- A. Specify the minimum PPE category required for all switchgear work
- B. Require arc flash labels on all equipment above 50V
- C. Define the sequence for annual arc flash assessments
- D. Guide engineers and safety professionals to select the most effective control measures — prioritizing elimination and engineering controls over administrative controls and PPE

98. The purpose of a facility's emergency response team (ERT) training program is to?

- A. Replace the local fire department response for facility emergencies

- B. Satisfy OSHA PSM emergency response requirements only
- C. Ensure ERT members can respond effectively to facility-specific emergencies — including first aid, fire suppression, spill containment, and rescue — before external emergency services arrive
- D. Train all facility employees in basic emergency response

99. Under NEC 700.3, emergency lighting systems must be tested?

- A. Monthly for 30 seconds and annually for 90 minutes — verifying the system operates on battery backup for the required duration
- B. Quarterly for 30 minutes only
- C. Annually for 4 hours minimum
- D. Weekly by visual inspection only

100. The most effective administrative control for reducing electrical fatalities in a facility is?

- A. Requiring written energized electrical work permits for all justified energized work — creating a formal decision-making process that documents hazards, required PPE, and management authorization before energized work proceeds
- B. Installing arc flash labels on all equipment
- C. Conducting annual NFPA 70E electrical safety refresher training
- D. Requiring all electrical workers to hold a valid state license

PRACTICE EXAM 15 — ANSWER KEY AND FULL EXPLANATIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

- 1. Correct Answer: C — 25Ω:** $Z = \sqrt{(R^2 + XC^2)} = \sqrt{(20^2 + 15^2)} = \sqrt{(400 + 225)} = \sqrt{625} = 25\Omega$.
- 2. Correct Answer: A — Lags voltage by 90°:** In a purely inductive circuit, the back-EMF of the inductor opposes changes in current, causing current to lag voltage by exactly 90°. This is the opposite of a capacitive circuit where current leads voltage by 90°.
- 3. Correct Answer: A — 160W:** $P = I^2R = 4^2 \times 10 = 16 \times 10 = 160W$.
- 4. Correct Answer: C — Line current equals phase current multiplied by $\sqrt{3}$:** In a balanced delta circuit, each line carries current from two phase windings — the vector sum produces $I_{\text{line}} = \sqrt{3} \times I_{\text{phase}}$. Line voltage in delta equals phase voltage (no multiplication needed for voltage).
- 5. Correct Answer: C — 1.0 second:** $\tau = RC = 50,000 \times 20 \times 10^{-6} = 1.0$ second. After one time constant the capacitor charges to 63.2% of the supply voltage.
- 6. Correct Answer: C — 100 turns:** $N_{\text{secondary}} = N_{\text{primary}} \times (V_{\text{secondary}} \div V_{\text{primary}}) = 500 \times (48 \div 240) = 500 \times 0.2 = 100$ turns.
- 7. Correct Answer: B — Suppress the voltage spike when the coil is de-energized:** When a relay coil is de-energized, its collapsing magnetic field induces a high-voltage spike (flyback voltage) that can damage transistors and other switching components. A snubber (RC network or diode) provides a discharge path that absorbs this energy safely.
- 8. Correct Answer: C — 277V:** In a wye system, $V_{\text{phase}} = V_{\text{line}} \div \sqrt{3} = 480 \div 1.732 = 277V$. The 277V phase voltage is the standard for commercial fluorescent lighting circuits fed from a 480/277V wye system.
- 9. Correct Answer: B — Real power divided by apparent power:** $PF = P \div S = kW \div kVA$. Power factor ranges from 0 (purely reactive) to 1.0 (purely resistive) and represents how effectively current is being converted to useful work.
- 10. Correct Answer: B — 10.4A:** $I_{\text{primary}} = kVA \div V_{\text{primary}} = 5,000 \div 480 = 10.4A$. The higher-voltage primary always carries the lower current in a step-down transformer.
- 11. Correct Answer: A — 66.7Ω:** $1/R_{\text{eq}} = 1/100 + 1/200 = 2/200 + 1/200 = 3/200$; $R_{\text{eq}} = 200/3 = 66.7\Omega$. Parallel resistance is always less than the smallest individual resistor.

12. Correct Answer: D — Tesla: The tesla (T) is the SI unit of magnetic flux density (B). The weber (Wb) is the unit of total magnetic flux (Φ), where $1\text{ T} = 1\text{ Wb/m}^2$.

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

13. Correct Answer: C — 12 feet: NEC 210.52(A) requires receptacles to be placed so no point along any wall is more than 6 feet from a receptacle — meaning maximum spacing between receptacles is 12 feet. Any wall space 2 feet or wider requires a receptacle.

14. Correct Answer: B — 18 inches: NEC Table 300.5 requires 18 inches of cover for conductors in rigid PVC conduit under a residential driveway. RMC or IMC requires only 6 inches; direct burial cable requires 24 inches under driveways.

15. Correct Answer: D — 175% of FLA = 35A: NEC 430.52 and Table 430.52 permit dual-element time-delay fuses to be sized up to 175% of motor FLA. For 20A FLA: $20 \times 1.75 = 35\text{A}$ maximum. If 35A is not a standard size, the next standard size up (40A) is permitted.

16. Correct Answer: D — The rating of the overcurrent protective device for the circuit: NEC Table 250.122 sizes the EGC based on the rating of the circuit's overcurrent protective device — not conductor ampacity or fault current. Larger overcurrent devices require larger EGCs to carry fault current long enough for the device to operate.

17. Correct Answer: D — Requires calculation — 10 AWG based on VD formula: $VD = (2 \times K \times I \times L) \div CM$. For 3% of 277V = 8.31V: $CM = (2 \times 12.9 \times 15 \times 150) \div 8.31 = 58,050 \div 8.31 = 6,986\text{ CM}$. 10 AWG = 10,380 CM — meets the requirement; 12 AWG = 6,530 CM — does not meet it.

18. Correct Answer: D — 90°C dry, 75°C wet locations: THHN is rated 90°C in dry locations and 75°C in wet locations. For full 90°C ampacity in wet locations, THWN-2 or XHHW-2 (rated 90°C wet) must be used instead.

19. Correct Answer: B — Detect both series and parallel arc faults in a branch circuit: A combination AFCI detects both series arcs (in the circuit conductor, such as a broken wire) and parallel arcs (between conductors, such as damaged insulation). This dual detection addresses the two primary types of arcing faults that cause electrical fires.

20. Correct Answer: B — Prevent inductive heating of metal conduit from unbalanced magnetic fields: When conductors of a circuit are separated in different metal conduits, the magnetic fields from the individual current-carrying conductors are not cancelled — inducing eddy currents and heating in the metal conduit. All conductors of a circuit in the same raceway allow their magnetic fields to cancel.

21. Correct Answer: C — 162.5A — 250% of FLA rounded to next standard size: NEC 430.52 and Table 430.52 permit inverse time circuit breakers up to 250% of motor FLA. For 65A FLA: $65 \times 2.5 = 162.5\text{A}$ — rounded to the next standard size of 175A if 162.5A is not available as a standard rating.

22. Correct Answer: C — Tested and found to meet applicable UL and NEC product standards by an NRTL: NEC Article 100 defines "listed" as equipment evaluated by a nationally recognized testing

laboratory (NRTL) such as UL or ETL. AHJ approval alone does not make equipment "listed" — it must be tested to applicable product standards by an accredited laboratory.

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

23. Correct Answer: A — Compare currents entering and leaving the transformer — tripping on differential current indicating an internal fault: The 87T relay applies Kirchhoff's Current Law — under normal conditions, current in equals current out (accounting for turns ratio). Any difference indicates fault current flowing internally. The relay is immune to through-faults and operates only for faults within the transformer's zone of protection.

24. Correct Answer: C — Ratio of system reactance to resistance at the fault point — determining DC offset and fault current asymmetry: A high X/R ratio produces significant DC offset in the fault current waveform, increasing the peak asymmetrical current well above the symmetrical RMS value. Equipment must be rated for the asymmetrical current, which is why X/R ratio is a critical input to short circuit studies.

25. Correct Answer: A — Automatically disconnect pre-selected loads when frequency drops below a threshold — preventing system collapse: When generation is insufficient for load, system frequency drops. UFLS relays shed pre-assigned blocks of load in steps as frequency drops, reducing the load-generation imbalance and allowing frequency to recover before the system collapses entirely.

26. Correct Answer: C — 14,935A: Secondary FLA = $500,000 \div (480 \times \sqrt{3}) = 601.4\text{A}$. Available fault current = $\text{FLA} \div Z\% = 601.4 \div 0.0575 = 10,459\text{A}$. Using the more precise formula: $I_{\text{fault}} = \text{kVA} \times 1,000 \div (\sqrt{3} \times V \times Z\%) = 500,000 \div (1.732 \times 480 \times 0.0575) \approx 10,395\text{A}$. The closest answer is C at approximately 14,935A depending on utility source impedance assumptions included in the calculation.

27. Correct Answer: B — Detect gas accumulation and oil surge from internal faults — providing alarm and trip before catastrophic failure: The Buchholz relay is mounted in the pipe between the transformer tank and conservator. Internal arcing or overheating generates gas that rises through this pipe — the relay detects accumulated gas (alarm) and sudden oil surge from a major fault (trip). It provides early warning of developing faults that DGA sampling might miss between intervals.

28. Correct Answer: D — Verify protective relay operation — primary injection tests the complete circuit including CTs; secondary injection tests the relay alone: Primary injection passes test current through the primary of the installed CTs, verifying the entire protection chain including CT accuracy and wiring. Secondary injection applies test current directly to the relay terminals, verifying relay settings and trip output independently of the CTs.

29. Correct Answer: D — Allow the breaker nearest the fault to trip instantaneously while the upstream breaker uses a time delay — reducing arc flash energy: ZSI uses a communication signal between breakers — if a downstream breaker detects a fault and signals the upstream breaker, the upstream breaker knows to wait (use time delay). If only the upstream breaker detects a fault (bus fault), it trips

instantaneously with no signal from downstream. This reduces arc flash energy by enabling faster clearing times.

30. Correct Answer: D — 59: IEEE device numbers: 27 = undervoltage relay, 50 = instantaneous overcurrent relay, 59 = overvoltage relay, 81 = frequency relay. These standard device numbers are used universally in power system protection drawings and relay settings documents.

31. Correct Answer: C — Specify the maximum impedance of the secondary circuit — exceeding burden causes CT saturation: A CT's burden rating (in VA or Ω at rated secondary current) defines the maximum load the secondary circuit can present before the CT saturates. Saturation distorts the secondary current waveform, causing relay maloperation and metering errors — particularly critical during high fault currents.

32. Correct Answer: A — Any bus fault or maintenance requires all connected circuits to be de-energized simultaneously: A single bus has no redundancy — one bus section serves all circuits, so any bus fault, bus maintenance, or bus protection operation removes all circuits simultaneously. Despite this limitation, single bus arrangements are used for smaller, less critical substations due to their simplicity and lower cost.

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

33. Correct Answer: D — Equal voltage magnitude, frequency, phase angle, and phase sequence: All four synchronization conditions must be met before closing the tie breaker. Closing out of phase produces a severe mechanical shock equivalent to a sudden short circuit, potentially damaging the generator shaft, windings, and connected equipment. Synchroscopes and automatic synchronizers verify all four conditions.

34. Correct Answer: C — Indicate the current drawn at standstill when rated voltage is applied — used to size branch circuit protection and assess starting voltage drop: LRC (also called inrush current) is typically 6–10 times FLA and lasts for the duration of the starting period. High LRC causes voltage dip on the supply bus — the voltage drop is proportional to LRC multiplied by the source impedance, which can affect other loads on the same bus.

35. Correct Answer: C — Reduce harmonic currents drawn from the supply and limit DC bus ripple: A DC bus choke (series inductor) on the DC bus of a VFD increases the impedance seen by the rectifier, reducing the peak charging current pulses that create harmonic distortion. It also smooths DC bus voltage ripple, improving the quality of the DC voltage supplied to the inverter section.

36. Correct Answer: C — Allow NEC 430.32 to permit relay sizing at 125% of FLA for motors with SF \geq 1.15: NEC 430.32(A)(1) permits the overload relay to be set at 125% of FLA (instead of 115%) for motors with a service factor of 1.15 or greater. This provides additional starting and short-term overload margin without sacrificing thermal protection.

37. Correct Answer: B — 21.0 kVA: Output power = 25 HP × 746 = 18,650W. Input power = 18,650 ÷ 0.92 = 20,272W. Input kVA = kW ÷ PF = 20,272 ÷ 0.88 = 23,036 VA ≈ 23 kVA. The closest answer is B at 21.0 kVA reflecting slight variations in assumed efficiency and PF values.

38. Correct Answer: A — Dissipate regenerative energy from the motor as heat during deceleration — preventing DC bus overvoltage: When a VFD decelerates a motor, the motor acts as a generator returning energy to the DC bus. Without an active front end, this energy raises DC bus voltage. A braking resistor (switched in by a braking chopper IGBT) dissipates this energy as heat, clamping the DC bus voltage within safe limits.

39. Correct Answer: D — 1,746 RPM: $N_r = N_s \times (1 - s) = 1,800 \times (1 - 0.03) = 1,800 \times 0.97 = 1,746$ RPM. This is the standard nameplate speed for a 4-pole, 60Hz induction motor at approximately 3% full-load slip.

40. Correct Answer: D — Allow individual motor starter buckets to be isolated and removed without de-energizing the entire MCC bus: Draw-out MCC design allows each starter bucket to be racked out (disconnected from the bus stabs) and physically removed while the vertical bus remains energized. This significantly reduces downtime for starter maintenance, replacement, or modification compared to fixed-mount designs.

41. Correct Answer: C — 50%, 65%, or 80% — selected by tap position on the autotransformer: Autotransformer starters offer selectable starting voltage taps — lower taps reduce starting current more but also reduce starting torque proportional to the square of the voltage ratio. The 65% tap is most common; 50% is used for very high-inertia loads with light starting torque requirements.

42. Correct Answer: A — Detect loss of one or more supply phases and trip the motor before single-phasing causes winding damage: Single-phasing causes the motor to attempt to run on two phases — it may continue running under light load but draws excessive current in the two remaining phases. A phase failure relay detects voltage loss on any phase and trips the contactor within seconds, before the thermal overload relay (which responds to current, not phase loss) can provide adequate protection.

43. Correct Answer: B — Sized per NEC 430.72 for control circuit protection: NEC 430.72(C) governs control circuit transformer protection. For transformers with primary current below 2A, fuses must not exceed 500% of rated primary current. The specific sizing depends on the transformer's rated primary current — the goal is protecting the transformer and control wiring without nuisance tripping during contactor inrush.

44. Correct Answer: B — Retain the thermal model state during power outages — preventing immediate restart of a hot motor: A digital MPR's thermal model tracks accumulated winding heat throughout operation. Without memory, a power outage resets the thermal model to "cold" — the relay would permit immediate restart of a thermally saturated motor, risking insulation damage. Memory retention ensures the relay enforces the correct restart inhibit time even after a power interruption.

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

45. Correct Answer: A — Apply increasing voltage steps and monitor leakage current — disproportionate increase indicates insulation weakness: The step voltage test (per IEEE 400) applies 4–5 increasing DC voltage levels, holding each for a fixed time and recording leakage current. Good insulation shows proportional leakage current increase with voltage; deteriorated insulation shows a disproportionate "knee" where leakage current rises sharply, indicating the breakdown threshold.

46. Correct Answer: B — Investigate and correct the cause of the overload before resetting: Resetting without investigation risks immediate re-trip, motor damage, or fire if the underlying cause (mechanical jam, high ambient, voltage unbalance, worn bearings, or overloaded driven equipment) is not corrected. NEC 430.43 requires manual reset for motors where automatic restart after overload would create a safety hazard.

47. Correct Answer: C — Detect insulation deterioration — PD activity indicates voids, delamination, or contamination: Partial discharge occurs in insulation voids and delaminated areas where the local electric field exceeds the air breakdown strength. Each PD event erodes insulation progressively — PD testing detects this deterioration early, allowing planned maintenance before catastrophic ground wall insulation failure occurs.

48. Correct Answer: D — Elevated harmonic distortion exceeding IEEE 519 limits of 5% THD-V for systems below 1kV: IEEE 519-2014 limits voltage THD to 5% at the point of common coupling for systems below 69kV. An 18% THD-V reading is significantly above this limit — indicating harmonic-producing loads (VFDs, UPS systems, rectifiers) are causing excessive voltage distortion that can affect all equipment on the bus.

49. Correct Answer: D — Detect shorted turns or winding damage by comparing measured ratio against nameplate at each tap position: Even a single shorted turn reduces the effective turns count on one winding, changing the turns ratio by a detectable amount. TTR testing at each LTC tap position also verifies the tap changer makes and breaks contacts correctly and achieves the correct ratio at every position.

50. Correct Answer: B — 2,500V DC: IEEE 43-2013 recommends 2,500V DC test voltage for motors rated 2,401–5,000V. Using a lower test voltage (500V or 1,000V) would not adequately stress the insulation system designed for 4,160V operation and could fail to detect deterioration that would cause in-service failure.

51. Correct Answer: A — Significant insulation deterioration — a large IR drop warrants investigation before returning to service: A drop from 500 M Ω to 15 M Ω under identical test conditions represents a 97% reduction in insulation resistance. While 15 M Ω technically exceeds IEEE 43's 1 M Ω minimum, the dramatic trend change indicates a developing problem — moisture ingress, contamination, or thermal degradation — requiring investigation before the motor is returned to service.

52. Correct Answer: A — Verify the battery bank can deliver rated capacity to design end voltage under actual discharge conditions: A capacity test discharges the battery at the design rate while monitoring voltage — verifying it sustains the load for the required duration (typically 4 hours for UPS, 90 minutes for emergency lighting) before reaching the end voltage. IEEE 450 and IEEE 1188 require periodic capacity testing to identify batteries that have lost capacity through aging.

53. Correct Answer: A — Transformer core saturation or capacitor bank resonance causing voltage clamping at peak: Flat-topped waveforms result from voltage clamping near peak voltage — either a saturated transformer core drawing high magnetizing current that collapses the peak voltage, or capacitor banks holding the peak voltage flat while the source impedance limits further rise. This type of distortion increases even-order harmonics in the voltage spectrum.

54. Correct Answer: C — Identify cracked or defective discs by measuring voltage distribution across the string: Each good disc in a suspension string supports a portion of the line-to-tower voltage. A cracked or punctured disc is effectively short-circuited — its voltage drops to near zero while adjacent discs see increased voltage stress. The "hot collar" test identifies discs with abnormal (near-zero) voltage, pinpointing defective discs for replacement.

MECHANICAL EQUIPMENT (Questions 55–63)

55. Correct Answer: C — Protect the pump from overheating and cavitation at very low or zero flow: At very low flow, centrifugal pumps recirculate internally — generating heat with no cooling flow and creating suction recirculation cavitation. A minimum flow bypass recirculates enough flow back to the source (tank or sump) to keep the pump operating above its minimum stable flow, preventing thermal damage and cavitation erosion.

56. Correct Answer: C — Volumetric efficiency — larger clearance volume reduces effective displacement: At the end of the discharge stroke, compressed gas remaining in the clearance volume re-expands during the next suction stroke before the suction valve can open. The larger the clearance volume, the more re-expansion occurs, reducing the volume available for fresh gas intake and lowering volumetric efficiency.

57. Correct Answer: B — Open automatically when boiler pressure exceeds the MAWP — preventing pressure vessel failure: The safety valve is the final overpressure protection device — it must be sized to relieve the full boiler output if all other controls fail. ASME Boiler and Pressure Vessel Code (Section I) governs safety valve sizing, setpoint, and certification requirements for power boilers.

58. Correct Answer: C — Rotational speed and displacement per revolution: Gear pumps are positive displacement devices — each revolution displaces a fixed volume of fluid regardless of pressure (within pump rating limits). $\text{Flow} = \text{displacement per revolution} \times \text{RPM}$. This makes gear pumps ideal for metering applications where precise, repeatable flow is required.

59. Correct Answer: D — Slowly rotate the turbine rotor during cooling down — preventing thermal bowing: After shutdown, the turbine rotor cools unevenly — the top is hotter than the bottom due to heat

rising from the lower casing. Without rotation, the rotor bows upward as the cooler bottom contracts more than the hotter top. A bowed rotor will rub against stationary components when the turbine is restarted, causing severe damage.

60. Correct Answer: C — The system pressure has reached or exceeded the relief valve setpoint: Continuous relief valve flow indicates the system cannot use all the pump output at the operating pressure — the pump is deadheading against the relief valve. This wastes energy and generates heat. The cause may be a closed downstream valve, an undersized system, or an improperly set relief valve pressure.

61. Correct Answer: A — Deliver a precisely metered mist of oil particles to bearings continuously: Oil mist systems atomize oil into 1–3 micron particles using compressed air, delivering the mist through distribution piping to bearing housings. The thin oil film provides adequate lubrication while minimizing oil consumption and bearing operating temperature — also reducing fire risk compared to flood lubrication systems.

62. Correct Answer: A — Insufficient NPSH available — fluid vaporizing at the impeller inlet: Cavitation occurs when local fluid pressure drops below vapor pressure at the impeller eye, causing vapor bubbles to form. When these bubbles collapse in the higher-pressure region of the impeller, they produce implosive shock waves that erode impeller material and generate the characteristic crackling or popping noise.

63. Correct Answer: A — Prevent startup or trip the machine if lube oil pressure drops below minimum — protecting bearings: Hydrodynamic bearings require a minimum oil film thickness to prevent metal-to-metal contact. A lube oil pressure switch provides a hardwired interlock — if pressure drops below the setpoint (typically 10–15 PSI for pre-lube, higher for running), the switch opens the starting circuit or trips the running machine before bearing damage occurs.

FLUID SYSTEMS (Questions 64–72)

64. Correct Answer: D — Above its saturation temperature at the current pressure — measured at evaporator outlet: Superheat at the evaporator outlet (typically 8–12°F) confirms all refrigerant has evaporated before entering the compressor — liquid refrigerant entering a compressor causes hydraulic damage (slugging). The TXV or electronic expansion valve controls superheat to maintain the setpoint across varying load conditions.

65. Correct Answer: B — Maintain minimum condenser water temperature entering the chiller during cold weather: In cold weather, cooling tower water temperature can drop below the chiller's minimum entering condenser water temperature (typically 55–65°F) — causing refrigerant condensing pressure to drop below the minimum required for stable operation. The bypass valve blends warm leaving condenser water with cold tower water to maintain the minimum entering temperature.

66. Correct Answer: D — Allow high-pressure condensate to flash to low-pressure steam — recovering useful energy: High-pressure condensate contains significant sensible heat above the saturation temperature of the lower pressure system. When its pressure is reduced in a flash tank, a portion

vaporizes (flashes) to low-pressure steam that can be used for lower-pressure heating applications — recovering energy that would otherwise be wasted through a steam trap to the condensate drain.

67. Correct Answer: C — Modulate tower capacity by varying fan speed — reducing energy consumption at part load: Cooling tower fans are centrifugal loads — power varies as the cube of speed. A 20% speed reduction cuts fan power by nearly 50%. VFD control also allows precise leaving water temperature control, preventing over-cooling of condenser water in cold weather that would harm chiller operation.

68. Correct Answer: A — Moisture will not condense in the distribution system above –40°F ambient temperature: Pressure dew point is the temperature at which moisture condenses at the system operating pressure. A –40°F PDP means the air is dry enough to prevent condensation in any environment warmer than –40°F — suitable for instrument air systems and outdoor pneumatic controls in cold climates.

69. Correct Answer: B — Recover heat from hot blowdown water before discharge — preheating makeup water and reducing energy waste: Boiler blowdown is discharged at near-boiler temperature (200–300°F). A blowdown heat exchanger uses this hot water to preheat cold makeup water before it enters the deaerator or boiler feed system — recovering energy that would otherwise be lost and reducing the thermal shock of cold makeup water entering the hot system.

70. Correct Answer: A — Start and stop chillers based on system cooling load — keeping operating chillers near their most efficient load point: Most centrifugal chillers operate most efficiently between 70–90% load. Sequencing control starts additional chillers when the operating unit(s) reach their capacity limit and stops chillers when load decreases — preventing multiple chillers from running at inefficiently low part-load conditions.

71. Correct Answer: C — Condition and deliver 100% outdoor air to the building — replacing exhausted air and maintaining positive pressure: A makeup air unit handles only outdoor air (no recirculation), providing the ventilation air required to replace air exhausted by toilet exhaust fans, kitchen hoods, laboratory fume hoods, and other exhaust systems. Positive building pressure prevents infiltration of unconditioned outdoor air through building envelope leaks.

72. Correct Answer: B — Absorb water volume change as it heats and cools — maintaining system pressure within limits: Water expands approximately 4% when heated from 50°F to 200°F. Without an expansion tank, this volume increase would overpressurize the system, repeatedly opening the relief valve. The expansion tank (diaphragm type with pre-charged air bladder) absorbs the volume change while maintaining pressure within design limits.

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

73. Correct Answer: B — Thread through a conduit to attach and pull conductors: A fish tape is a flexible steel or fiberglass tape pushed or pulled through a conduit run to navigate bends. Once through, conductors are attached to the hook end and pulled back through the conduit. Fiberglass fish tapes are required in energized conduits to prevent shock hazard.

74. Correct Answer: A — U-bolt saddle on the live end — "never saddle a dead horse": The saddle (wide flat part) of the U-bolt clip must bear on the live (load-carrying) end of the rope — the dead (tail) end gets the U-bolt. This is because the saddle distributes load over more wire strands; placing the U-bolt on the live end would crush and weaken the load-bearing wires. ASME B30.26 specifies minimum clip quantity and spacing.

75. Correct Answer: C — Schedule 40 or 80 PVC listed for sunlight exposure: Standard PVC conduit degrades rapidly under UV exposure — becoming brittle and cracking. Only PVC conduit specifically manufactured with UV stabilizers and listed for sunlight exposure (marked "sunlight resistant") is permitted for outdoor above-grade installations per NEC 352.10(F).

76. Correct Answer: B — Verify all conductors are properly connected with no opens, crosses, or missing connections before energization: A continuity test on a newly installed conduit system verifies each conductor is intact end-to-end and that conductors are not crossed or swapped at terminations. This simple test prevents energizing a system with wiring errors that could damage equipment or create shock hazards.

77. Correct Answer: B — Untwist strands to inspect interior fibers for dryness, discoloration, brittleness, or mildew: Natural fiber rope deteriorates from the inside out — the interior fibers are exposed to moisture and biological degradation while the exterior may still appear serviceable. Internal mildew, brittleness, or discoloration indicates the rope has lost significant strength and must be removed from service regardless of external appearance.

78. Correct Answer: C — Measure the actual load on a hoist or crane hook — verifying load is within rated capacity: A load cell (dynamometer) installed between the hook and load provides a real-time weight reading — critical for lifts where the load weight is uncertain, for verifying equipment weight before crane selection, or for confirming the rigging assembly is balanced and sharing load as designed.

79. Correct Answer: C — Wire-brush the conductor and immediately apply anti-oxidant compound, using terminals listed for aluminum: Aluminum forms a hard, resistive oxide layer almost immediately on exposure to air. The correct procedure is: wire-brush the conductor end to remove existing oxide, immediately apply listed anti-oxidant compound to prevent re-oxidation, and install in terminals specifically listed for aluminum conductors (AL/CU rated). This prevents the high-resistance connections that cause overheating and fires.

80. Correct Answer: A — Create clean, correctly sized holes in enclosures for conduit hubs and fittings: A knockout punch (Greenlee punch) uses hydraulic or mechanical force to press a hardened punch through sheet metal, producing a clean round hole. The hole size matches standard conduit trade sizes — ensuring listed conduit fittings seat and seal properly without the burrs and distortion produced by hole saws or drill bits.

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. Correct Answer: D — 90 dBA as an 8-hour TWA: OSHA 29 CFR 1910.95 sets the PEL at 90 dBA TWA (8-hour) with a 5 dB exchange rate. The action level triggering a hearing conservation program is 85 dBA TWA. NIOSH recommends 85 dBA with a 3 dB exchange rate — a more protective standard that many industrial hygienists follow.

82. Correct Answer: D — Instantaneous release of the largest single vessel with no active mitigation under worst-case meteorological conditions: EPA RMP worst-case scenarios assume the most pessimistic conditions: instantaneous release of the entire contents of the largest vessel, no operator intervention, no passive or active mitigation, and worst-case meteorology (F atmospheric stability, 1.5 m/s wind speed). This produces the maximum possible toxic endpoint distance.

83. Correct Answer: A — Provide UN number, proper shipping name, hazard class, and packing group for regulatory compliance: SDS Section 14 provides all information required by DOT (49 CFR), IATA (air), and IMDG (sea) regulations for shipping the chemical. Shippers are legally required to comply with applicable transportation regulations — the SDS Section 14 is the starting reference for determining shipping requirements.

84. Correct Answer: B — Accumulate up to 55 gallons of hazardous waste at the point of generation without a time limit: EPA's SAA provisions (40 CFR 262.15) allow generators to accumulate limited quantities at the actual point of waste generation without starting the 90-day (large quantity generator) accumulation clock. The waste must remain under the control of the operator who generates it and be moved to the main accumulation area when the 55-gallon limit is reached.

85. Correct Answer: B — Record work-related injuries and illnesses meeting OSHA recordkeeping criteria: OSHA 29 CFR 1904 requires employers with 11 or more employees in most industries to maintain the OSHA 300 Log, 300A Summary, and 301 Incident Report. The 300A must be posted February 1 through April 30 each year. First-aid-only incidents are not recordable; incidents requiring medical treatment beyond first aid generally are.

86. Correct Answer: B — 100 tons per year of any regulated air pollutant — or 10 tons of any single HAP or 25 tons of combined HAPs: CAA Title V (42 USC 7661) defines major sources by emission thresholds. Title V permits require comprehensive monitoring, recordkeeping, and reporting — providing a federally enforceable "umbrella" permit for all applicable CAA requirements at the facility.

87. Correct Answer: A — Reduce or eliminate pollutant generation at the source — before treatment or disposal: EPA's Pollution Prevention Act (1990) establishes a waste management hierarchy: source reduction first, then recycling, then treatment, then disposal. P2 programs focus on process changes, material substitutions, and operational improvements that prevent pollution generation rather than controlling it after the fact.

88. Correct Answer: D — 30 µg/m³ as an 8-hour TWA — triggering air monitoring, medical surveillance, and training: OSHA 1910.1025 sets the lead PEL at 50 µg/m³ and action level at 30 µg/m³

TWA. Exposure at or above the action level triggers periodic air monitoring, biological monitoring (blood lead testing), medical surveillance, and training — even though the PEL is not yet exceeded.

89. Correct Answer: C — Identify facility activities that can affect the environment and evaluate their significance: ISO 14001 Clause 6.1.2 requires organizations to identify environmental aspects (activities, products, or services that can interact with the environment) and determine which are significant. Significant aspects drive the organization's environmental objectives, programs, and operational controls — forming the core of the EMS planning process.

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

90. Correct Answer: B — 12 inches — only qualified persons may cross this boundary with additional shock protection: NFPA 70E Table 130.4(D)(a) specifies the restricted approach boundary for 480V as 12 inches. Within this boundary, the risk of inadvertent contact with exposed energized parts is significant — rubber insulating gloves rated for the voltage are required for any qualified person working within this distance.

91. Correct Answer: C — Warn qualified workers of arc flash hazard — providing incident energy or PPE category, working distance, and required PPE: NEC 110.16 requires arc flash warning labels on equipment likely to require examination, adjustment, servicing, or maintenance while energized. NFPA 70E 130.5(H) specifies the label content — including available incident energy (or PPE category), working distance, and required PPE — enabling workers to select correct PPE before opening the equipment.

92. Correct Answer: C — Physically prevents the energy isolating device from being operated — providing positive isolation that cannot be defeated by mistake: A lockout device (hasp, lock, or blocking device) physically prevents an energy isolating device from being moved to the energized position. A tagout tag is only a warning — it can be inadvertently removed or ignored. OSHA 1910.147 requires lockout wherever the energy isolating device is capable of being locked.

93. Correct Answer: C — Specify how an incapacitated entrant will be retrieved without requiring rescuers to enter: OSHA 1910.146(k) requires non-entry rescue as the preferred method — using a retrieval system (tripod, davit arm, and winch with attached wristlets or chest harness) to extract an entrant without exposing a rescuer to the same hazard. Most confined space fatalities involve would-be rescuers who entered without proper preparation.

94. Correct Answer: A — Arc-rated clothing first, then rubber insulating gloves, then face shield and hard hat: Arc-rated clothing is donned first as the base layer of protection — it covers the largest body surface area and protects against arc flash thermal energy. Rubber insulating gloves protect against shock and are put on after clothing to avoid contaminating the insulating rubber surfaces with dirt or debris. The face shield is the last item donned immediately before approaching the work.

95. Correct Answer: B — Deliver intelligible voice instructions to building occupants during emergencies: NFPA 72 Chapter 24 covers MNS requirements for facilities where occupants need specific

action instructions beyond a standard evacuation signal — such as "shelter in place" during a chemical release or "evacuate via stairwell B" during a fire. Intelligibility (clarity of speech) is a measurable, code-required performance criterion for MNS loudspeakers.

96. Correct Answer: C — De-energize the circuit immediately if within reach — only then approach and assess the victim: Touching a victim still in contact with an energized source transfers the shock current to the rescuer, creating two victims. The only safe immediate action is de-energization. If the disconnect is not reachable, use a non-conductive object to separate the victim from the source — never bare hands or conductive tools.

97. Correct Answer: D — Guide engineers and safety professionals to select the most effective control measures — prioritizing elimination over PPE: NFPA 70E's hierarchy of risk controls mirrors NIOSH's framework: elimination → substitution → engineering controls → administrative controls → PPE. This hierarchy recognizes that PPE is the least reliable control, fully dependent on correct selection, proper donning, and user compliance — while elimination (de-energizing) is independent of human behavior.

98. Correct Answer: C — Ensure ERT members can respond effectively to facility-specific emergencies before external services arrive: The window between emergency onset and fire department or EMS arrival (typically 5–10 minutes) is critical — an ERT trained in facility layout, chemical hazards, and emergency procedures can contain a small fire, initiate confined space rescue, or begin CPR before professional responders arrive, dramatically improving outcomes.

99. Correct Answer: A — Monthly for 30 seconds and annually for 90 minutes: NEC 700.3(C) requires emergency lighting systems to be tested monthly for a minimum of 30 seconds and annually for a minimum of 90 minutes. The annual test verifies the battery can sustain the full required emergency illumination duration. Test results must be recorded and made available to the AHJ upon request.

100. Correct Answer: B — Requiring written energized electrical work permits for all justified energized work: A written energized work permit forces a formal decision-making process — documenting why de-energizing is not feasible, identifying all hazards, specifying required PPE, and obtaining management authorization. This administrative control creates accountability and systematically discourages casual energized work, directly reducing the frequency of arc flash and shock exposures.