

PRACTICE EXAM 16: STATIONARY ENGINEER (ELECTRIC) SIMULATION — 100 QUESTIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. A 240V DC circuit has a 30Ω resistor and a 10Ω internal resistance in series. The terminal voltage across the external resistor is?

- A. 240V
- B. 200V
- C. 60V
- D. 180V

2. The property of a capacitor that opposes changes in voltage is called?

- A. Capacitive reactance
- B. Inductive impedance
- C. Dielectric resistance
- D. Charge resistance

3. A 3-phase, 480V, balanced wye load draws 20A per phase at unity power factor. The total three-phase power is?

- A. 9,600W

- B. 14,400W
- C. 19,200W
- D. 16,627W

4. In a series RLC circuit at resonance, the impedance is?

- A. Equal to the resistance R only
- B. Equal to $X_L + X_C$
- C. Zero
- D. Equal to $X_L - X_C$

5. A coil has an inductance of 200mH. At 60Hz, its inductive reactance is?

- A. 120Ω
- B. 200Ω
- C. 75.4Ω
- D. 37.7Ω

6. The term "apparent power" in an AC circuit is measured in?

- A. Volt-amperes (VA)
- B. Watts (W)
- C. VAR
- D. Joules

7. A capacitor of $50\mu\text{F}$ is connected to a 120V, 60Hz supply. The capacitive reactance is?

- A. 106Ω
- B. 53.1Ω
- C. 26.5Ω
- D. 212Ω

8. In a transformer, the primary and secondary voltages are related by?

- A. The ratio of secondary to primary resistance
- B. The ratio of primary to secondary impedance
- C. The square of the turns ratio
- D. The turns ratio N_1/N_2

9. The purpose of a fuse in a DC circuit is to?

- A. Regulate voltage across the load
- B. Filter ripple voltage from the supply
- C. Protect the circuit by opening on overcurrent
- D. Limit inrush current during startup

10. Fleming's Right-Hand Rule applies to?

- A. The force on a current-carrying conductor in a magnetic field
- B. The direction of current in a motor armature
- C. The direction of magnetic flux around a conductor
- D. The direction of induced EMF in a conductor moving through a magnetic field

11. The dielectric strength of an insulating material is defined as?

- A. The material's ability to store electrical charge
- B. The resistance per unit length of the material
- C. The temperature at which the material loses its insulating properties
- D. The maximum electric field (V/m) the material can withstand without breakdown

12. Two capacitors of $20\mu\text{F}$ and $30\mu\text{F}$ are connected in series. The equivalent capacitance is?

- A. $50\mu\text{F}$
- B. $10\mu\text{F}$
- C. $12\mu\text{F}$
- D. $25\mu\text{F}$

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

13. The NEC definition of a "branch circuit" is the circuit conductors between?

- A. The service entrance and the first overcurrent device
- B. The final overcurrent protective device and the outlets
- C. The meter and the main panel
- D. Two overcurrent devices in series

14. Per NEC 408.36, a panelboard must be protected by an overcurrent device having a rating not exceeding?

- A. 200A regardless of panelboard rating

- B. The ampacity of the panelboard bus
- C. 125% of the panelboard's continuous load rating
- D. The ampere rating of the panelboard

15. The purpose of a bonding bushing on a rigid metal conduit entry into a service equipment enclosure is to?

- A. Provide a watertight seal at the conduit entry
- B. Reduce conduit vibration transmitted to the panel
- C. Provide a bonding path around the concentric knockout to maintain low-impedance equipment grounding continuity
- D. Secure the conduit mechanically to the panel enclosure

16. Type NM cable (Romex) is permitted in which of the following locations?

- A. Wet locations if protected by conduit
- B. Exposed in commercial garages
- C. In air ducts and plenums if plenum-rated
- D. Dry locations in one- and two-family dwellings and multi-family dwellings not exceeding three floors

17. Under NEC 240.21(B), tap conductors from a feeder are permitted without overcurrent protection at the tap point if they are not longer than 10 feet and?

- A. Protected by the feeder overcurrent device only
- B. Have an ampacity of at least 10% of the feeder overcurrent device rating and terminate in a single overcurrent device
- C. Are installed in conduit for their entire length
- D. Are the same size as the feeder conductors

18. The purpose of a ground fault protection of equipment (GFPE) device required by NEC 230.95 on services of 150V to ground or less, 1,000A or more is to?

- A. Provide shock protection for personnel at the service
- B. Detect low-level ground faults that would not trip the main overcurrent device — preventing the sustained arcing ground fault from causing fires in switchboards and panelboards
- C. Replace the main service overcurrent protective device
- D. Protect individual branch circuits from ground fault currents

19. The minimum headroom required in front of electrical equipment rated 600V or less per NEC 110.26(A)(3) is?

- A. 5.5 feet
- B. 6.0 feet
- C. 6.5 feet
- D. 7.0 feet

20. Per NEC 314.28, pull boxes for conductors 4 AWG or larger must have a minimum distance between conduit entries on the same wall equal to?

- A. 6 times the trade diameter of the largest conduit
- B. 8 times the trade diameter of the largest conduit for straight pulls
- C. 12 times the trade diameter of the largest conduit
- D. 4 times the trade diameter of the largest conduit

21. The purpose of a listed arc fault circuit interrupter (AFCI) outlet device is to?

- A. Provide GFCI protection in addition to arc fault protection

- B. Replace the requirement for an AFCI circuit breaker in existing wiring
- C. Protect only the outlet where installed
- D. Provide arc fault protection for the outlet and all downstream outlets on the same circuit when installed as the first outlet from the panel

22. Conductors in a conduit system that are not counted as current-carrying conductors for derating purposes include?

- A. All grounded (neutral) conductors
- B. Equipment grounding conductors and neutral conductors of 3-phase, 4-wire wye circuits supplying only linear loads
- C. Equipment grounding conductors and grounded conductors in multi-wire branch circuits
- D. Both EGCs and all neutral conductors regardless of load type

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

23. The purpose of a power system stability study is to?

- A. Determine whether generators and motors will remain in synchronism following disturbances — identifying system weaknesses that could lead to loss of synchronism and cascading outages
- B. Calculate steady-state voltage profiles across the system under normal loading
- C. Determine the maximum fault current at each bus under bolted fault conditions
- D. Evaluate the thermal loading of transmission lines during contingency conditions

24. In a high-voltage substation, the purpose of a potential transformer (PT) is to?

- A. Step up voltage for transmission to remote loads
- B. Measure primary fault current for relay input

- C. Step down high voltage to a safe level (typically 120V) for metering and relaying
- D. Provide voltage regulation for the substation bus

25. The purpose of a recloser on a distribution feeder is to?

- A. Provide backup protection for the substation transformer
- B. Measure power quality at the distribution level
- C. Automatically interrupt fault current and reclose after a time delay — clearing temporary faults (tree contact, animal contact) without permanent outage
- D. Regulate voltage at the end of long feeder runs

26. A current transformer with a ratio of 400:5 has a primary current of 320A. The secondary current is?

- A. 5A
- B. 3.2A
- C. 4A
- D. 2.5A

27. The purpose of a "transfer trip" scheme in transmission line protection is to?

- A. Automatically transfer load to a backup line when the primary line trips
- B. Send a direct trip signal to the remote end breaker when a fault is detected at the local end — ensuring both ends of a faulted line are cleared simultaneously
- C. Trip the line breaker when power transfer exceeds the thermal rating
- D. Provide backup protection for breaker failure at the remote terminal

28. In a gas-insulated switchgear (GIS) system, the insulating medium is?

- A. Mineral oil under pressure
- B. Sulfur hexafluoride (SF₆) gas
- C. Dry nitrogen at atmospheric pressure
- D. Compressed air at 150 PSI

29. The purpose of a "cold load pickup" scheme in distribution automation is to?

- A. Automatically restore power to all customers simultaneously after an outage
- B. Test feeder insulation before re-energization after an extended outage
- C. Monitor feeder loading during cold weather peak demand
- D. Gradually restore load after an extended outage to prevent overloading the feeder from the simultaneous inrush of all restored loads

30. The IEEE device number for a directional overcurrent relay is?

- A. 67
- B. 51
- C. 27
- D. 50N

31. The purpose of an oil circuit breaker's (OCB) oil is to?

- A. Lubricate the operating mechanism for reliable contact opening
- B. Provide cooling to the breaker contacts during normal load flow
- C. Insulate between phases only — arc interruption uses air
- D. Quench the arc between opening contacts and provide electrical insulation between phases

31. The purpose of a neutral grounding reactor (NGR) vs. a neutral grounding resistor in a medium-voltage system is to?

- A. Limit ground fault current while allowing the system to continue operating with a single line-to-ground fault — the reactor's low DC resistance minimizes power loss during normal operation while limiting fault current
- B. Eliminate ground fault current entirely
- C. Provide faster fault clearing than a resistor
- D. Reduce the system's zero-sequence impedance

32. In a unit substation, the "primary" section refers to?

- A. The incoming high-voltage section containing the primary disconnect switch and primary fusing or breaker
- B. The transformer section only
- C. The secondary low-voltage distribution section
- D. The metering compartment at the top of the switchgear

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

33. The purpose of a generator's automatic voltage regulator (AVR) is to?

- A. Control generator real power output by adjusting the prime mover speed
- B. Protect the generator from overvoltage during load rejection
- C. Maintain constant terminal voltage by adjusting field excitation current in response to load changes
- D. Synchronize the generator with the bus before parallel operation

34. A 100 kW, 480V, 3-phase generator at 0.8 PF lagging has an armature current of approximately?

- A. 150A
- B. 120A
- C. 208A
- D. 240A

35. The purpose of a motor's "thermal memory" in a digital overload relay is to?

- A. Log the number of starts and runtime hours for maintenance scheduling
- B. Model accumulated winding heat based on current history — preventing restart if the motor is too hot even after a brief power outage
- C. Record peak current during each starting event
- D. Calculate motor efficiency from current and voltage measurements

36. In a wound rotor motor, the external rotor resistance is gradually reduced as the motor accelerates because?

- A. Lower resistance increases motor efficiency at full load
- B. Reduced resistance reduces brush sparking during normal running
- C. Maximum torque occurs at a slip value where rotor resistance equals rotor reactance — reducing resistance as speed increases keeps maximum torque near the operating speed throughout acceleration
- D. Higher resistance at full speed increases motor power factor

37. A 480V, 3-phase, 50 HP induction motor has a full-load efficiency of 93% and PF of 0.89. The full-load line current is approximately?

- A. 65.2A

B. 55.8A

C. 72.1A

D. 48.3A

38. The purpose of a "jogging" function in a motor control circuit is to?

A. Provide slow-speed operation using a reduced-voltage starting method

B. Limit the number of starts per hour to protect the motor thermally

C. Momentarily energize the motor contactor for short bursts of movement — used for precise positioning without the motor latching into continuous run mode

D. Test the motor direction before coupling to the load

39. In a VFD application, the "volts per hertz (V/Hz)" ratio is maintained constant below base speed to?

A. Prevent motor overspeed during rapid acceleration

B. Limit motor starting current to 150% of FLA

C. Maintain constant motor air gap flux — preventing magnetic saturation at low speed and ensuring rated torque is available throughout the speed range

D. Protect the VFD IGBTs from overvoltage during deceleration

40. The purpose of a "speed droop" setting on a generator governor is to?

A. Limit generator acceleration during startup to prevent overspeed

B. Control the generator's reactive power output during parallel operation

C. Prevent the generator from hunting (oscillating speed) during transient load changes

D. Allow stable load sharing between generators operating in parallel by reducing speed slightly as load increases

41. A three-phase motor nameplate reads: 460V, 60Hz, 1,750 RPM, 40A FLA, SF 1.15. The maximum continuous current this motor can carry without exceeding its thermal rating is?

- A. 40A
- B. 44A
- C. 46A
- D. $40A \times 1.15 = 46A$ — service factor current is $FLA \times SF$

42. The purpose of a soft starter's "current limit" function is to?

- A. Protect the soft starter SCRs from overheating
- B. Prevent the motor from drawing more than rated current during starting
- C. Limit motor speed during the acceleration ramp
- D. Cap motor starting current at a user-set maximum — reducing voltage dip on the supply bus and mechanical shock to the driven equipment during starting

43. In a DC motor, increasing the field current while keeping armature voltage constant will?

- A. Increase motor speed
- B. Decrease motor speed — back-EMF is proportional to $\text{flux} \times \text{speed}$; increased flux requires speed to decrease to maintain the same back-EMF at constant armature voltage
- C. Increase armature current only
- D. Have no effect on motor speed

44. The purpose of an "anti-backspin" device on a vertical turbine pump motor is to?

- A. Prevent motor overspeed if the pump discharge valve opens too quickly

- B. Prevent the pump from rotating backward during coastdown after shutdown — backflow through the pump can spin it in reverse, and energizing a backward-spinning motor causes severe electrical and mechanical shock
- C. Limit pump speed during priming
- D. Protect the thrust bearing from excessive downthrust during starting

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

45. When a circuit breaker fails to trip during a ground fault test, the most likely cause is?
- A. The breaker's trip rating is too high for the test current injected
 - B. An open or high-resistance connection in the ground fault relay's trip circuit — the relay may have operated correctly but the trip signal did not reach the breaker trip coil
 - C. The breaker contacts are welded closed
 - D. The ground fault relay setpoint is set below the test current level
46. The purpose of performing a "dielectric absorption ratio" (DAR) test is to?
- A. Measure insulation resistance at multiple frequencies
 - B. Compare conductor resistance at different temperatures
 - C. Test the cable's capacitance to ground
 - D. Assess insulation condition by comparing 30-second and 60-second IR readings — a ratio below 1.25 indicates wet or contaminated insulation
47. When using a clamp-on ammeter to measure current in a single-phase circuit, the correct procedure is to?
- A. Clamp around both the hot and neutral conductors simultaneously

B. Clamp around one conductor only — clamping both conductors cancels the magnetic fields, producing a zero reading

C. Clamp around the equipment grounding conductor for the most accurate reading

D. Clamp around all conductors including the ground for total circuit current

48. The purpose of a transformer oil dielectric strength test (ASTM D877) is to?

A. Measure the acid number of the transformer oil

B. Determine the breakdown voltage of the oil — verifying it can withstand operating voltage stress; low dielectric strength indicates moisture or particulate contamination requiring oil treatment or replacement

C. Assess oil oxidation products that indicate aging

D. Measure dissolved gas content to identify fault gases

49. When troubleshooting a 3-phase motor that runs hot at normal load, the first measurement to take is?

A. Insulation resistance with a megohmmeter

B. Line current on all three phases — to identify phase imbalance, overcurrent, or single-phasing that would cause excess heating

C. Winding resistance of all three phases

D. Bearing temperature at both drive end and non-drive end

50. The purpose of a thermographic (infrared) survey on a medium-voltage switchgear lineup is to?

A. Verify arc flash incident energy levels match the arc flash labels

B. Detect hot spots from loose connections, overloaded components, or failing equipment — before thermal damage leads to failure or fire

C. Measure ambient temperature inside the switchgear for ventilation adequacy

D. Verify cooling fan operation in forced-air-cooled switchgear

51. A power factor correction capacitor bank shows a measured capacitance 15% below its nameplate rating. This indicates?

- A. Normal capacitor aging within acceptable tolerance
- B. The capacitors need recharging to restore rated capacitance
- C. One or more capacitor elements within the bank have failed open — reducing total capacitance and reactive power output, requiring capacitor replacement
- D. The test was performed at the wrong voltage level

52. The purpose of a surge arrester's "discharge voltage" rating is to?

- A. Define the maximum continuous operating voltage the arrester can withstand
- B. Specify the voltage across the arrester terminals during a discharge event — the clamping voltage that determines how much overvoltage reaches protected equipment
- C. Define the energy rating in joules for impulse discharge capability
- D. Specify the arrester's short circuit current rating

53. When a 480V motor trips on overload immediately after starting (within 2–3 seconds), the most likely cause is?

- A. Loose connection at the motor terminal box
- B. The overload relay is sized too low for the motor's locked rotor current — the relay cannot distinguish starting inrush from a fault and trips during the normal starting period
- C. Insulation failure between two stator phases
- D. Bearing seizure preventing the motor from accelerating

54. The purpose of a "tip-up" test (tan delta vs. voltage) on motor stator insulation is to?

- A. Measure the motor's insulation resistance at increasing voltage steps

- B. Detect conductor resistance changes caused by thermal cycling
- C. Identify thermal deterioration, delamination, or slot discharge — the increase in tan delta with voltage indicates stress-dependent loss mechanisms associated with insulation degradation
- D. Verify the motor winding's resistance to partial discharge

MECHANICAL EQUIPMENT (Questions 55–63)

55. The purpose of a pump's "net positive suction head required" (NPSHr) specification is to?

- A. Define the maximum discharge head the pump can develop
- B. Specify the minimum suction pressure needed to prevent cavitation at the impeller
- C. Define the minimum suction pipe diameter for the pump
- D. Specify the pump's efficiency at the best efficiency point

56. In a steam turbine, the purpose of "nozzle governing" (partial arc admission) at part load is to?

- A. Reduce turbine vibration by limiting steam admission to one side
- B. Maintain turbine efficiency at part load by admitting full-pressure steam through a portion of the nozzles rather than throttling all steam to a lower pressure
- C. Control turbine speed during startup by progressively opening nozzle groups
- D. Protect nozzles from erosion by limiting steam velocity at part load

57. The purpose of a boiler's deaerator (DA) is to?

- A. Remove suspended solids from feedwater before it enters the boiler
- B. Control feedwater flow rate to match steam demand
- C. Remove dissolved oxygen and other non-condensable gases from feedwater — preventing corrosion of boiler tubes, headers, and feedwater piping

D. Measure feedwater conductivity for water treatment control

58. A reciprocating air compressor's intercooler pressure gauge reads higher than normal between stages. This indicates?

A. The first stage is operating more efficiently than designed

B. The second stage discharge valve is partially restricted

C. The intercooler is providing more cooling than required

D. A restriction in the second stage inlet valve or cylinder — high interstage pressure indicates the second stage cannot accept gas at the normal rate, causing pressure to build between stages

59. The purpose of a mechanical seal flush plan (API Plan 11) in a pump application is to?

A. Provide a clean external fluid to cool and lubricate the mechanical seal faces

B. Isolate the seal from process fluid using a barrier fluid at higher pressure

C. Vent seal leakage to a collection system for environmental containment

D. Recirculate pumped fluid from the pump discharge through a flow control orifice back to the seal chamber — cooling and lubricating the seal faces using the process fluid

60. In a refrigeration system, high discharge pressure combined with normal suction pressure indicates?

A. Refrigerant undercharge

B. Condenser fouling, high ambient temperature, or non-condensable gases in the system — all of which reduce condenser heat rejection efficiency and raise condensing pressure

C. Expansion valve malfunction

D. Compressor valve leakage

61. The purpose of a turbine's "extraction steam" connection is to?

- A. Remove moisture from the steam at an intermediate stage to protect downstream blading
- B. Provide steam for turbine gland sealing
- C. Allow backpressure control for variable speed operation
- D. Bleed steam at an intermediate pressure point for feedwater heating or process use — improving overall plant thermodynamic efficiency

62. The purpose of a hydraulic system's accumulator is to?

- A. Filter hydraulic fluid before it reaches the control valves
- B. Store pressurized hydraulic fluid to supply instantaneous flow demands that exceed pump capacity, absorb pressure pulsations, and maintain pressure during pump off-cycles
- C. Regulate system pressure by bypassing excess flow
- D. Cool the hydraulic fluid during high-duty cycle operation

63. When a centrifugal pump's discharge pressure is significantly lower than expected at design flow, the most likely cause is?

- A. Excessive system resistance in the discharge piping
- B. Worn pump wear rings only
- C. Impeller wear, wrong impeller diameter, incorrect rotation direction, or air entrainment — all reduce the pump's ability to develop head at design flow
- D. Cavitation at the pump discharge

FLUID SYSTEMS (Questions 64–72)

64. The purpose of a "primary/secondary" chilled water piping arrangement is to?

- A. Separate the chiller evaporator circuits from the building distribution circuits — allowing independent flow control in each loop and preventing flow variation in the chiller loop when building zone valves modulate
- B. Provide redundant chilled water supply in case of pump failure
- C. Allow different chilled water supply temperatures in different building zones
- D. Eliminate the need for balancing valves in the distribution system

65. In a steam system, "flash steam" is produced when?

- A. Steam pressure in the main rises above design pressure
- B. Feedwater is injected into the steam main for humidity control
- C. Steam traps bypass live steam due to failure
- D. High-pressure condensate at elevated temperature is exposed to lower pressure — a portion vaporizes (flashes) because the condensate temperature exceeds the saturation temperature at the lower pressure

66. The purpose of a chilled water system's "common pipe" (decoupler) in a primary/secondary arrangement is to?

- A. Provide a bypass for chiller maintenance isolation
- B. Allow bidirectional flow between the primary and secondary loops — ensuring chiller flow remains constant when secondary flow demand is less than or greater than primary flow
- C. Balance flow between multiple chillers on the primary loop
- D. Provide a mixing point for different chilled water temperatures

67. In a compressed air system, why is a moisture separator installed downstream of the aftercooler?

- A. To filter oil aerosols before the air receiver
- B. To remove bulk liquid water that has condensed in the aftercooler before it enters the air receiver and distribution system
- C. To reduce air velocity before the receiver inlet
- D. To remove carbon monoxide from the compressed air

68. The purpose of a boiler's forced draft (FD) fan is to?

- A. Supply combustion air to the burner under positive pressure — ensuring adequate air for combustion at all firing rates and maintaining furnace positive pressure
- B. Exhaust flue gases from the furnace to the stack
- C. Recirculate flue gas back to the furnace for NO_x reduction
- D. Provide cooling air to the boiler air preheater

69. In a building automation system (BAS), a "PID" control loop refers to?

- A. A two-position (on/off) control algorithm
- B. A pressure-independent damper control sequence
- C. A proportional-integral-derivative control algorithm — combining proportional response, integral action to eliminate steady-state error, and derivative action to reduce overshoot
- D. A programmable interface device for field sensor communication

70. The purpose of an air handling unit's (AHU) mixing box dampers is to?

- A. Blend supply and return air to achieve the desired supply temperature without mechanical cooling
- B. Control supply air pressure to the distribution ductwork

- C. Provide smoke control by isolating the AHU from the return air system
- D. This is not a real AHU component — mixing boxes are found only in terminal units

71. The purpose of a steam system's pressure-reducing station (PRS) bypass line is to?

- A. Provide an alternate steam path if the PRV fails closed — allowing manual steam flow control during PRV maintenance or failure
- B. Increase steam flow capacity above the PRV's rated capacity during peak demand
- C. Allow the PRV to be tested under load without interrupting steam supply
- D. Prevent steam from back-flowing through the PRV during plant shutdown

72. In a chilled water plant, "chiller lift" refers to?

- A. The physical elevation difference between the chiller and the cooling tower
- B. The chiller's refrigerant compressor motor current at full load
- C. The temperature difference between the chilled water supply and condenser water supply
- D. The difference between condensing temperature and evaporating temperature — a key driver of chiller energy consumption; lower lift means lower compressor work and better efficiency

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

73. The purpose of a "come-along" (lever hoist) in electrical and mechanical work is to?

- A. Provide temporary support for conduit during installation
- B. Pull wire rope through underground conduit systems
- C. Tension wire rope guy wires on utility poles
- D. Apply controlled mechanical advantage for pulling, tensioning, or lifting loads — using a ratcheting lever mechanism to move loads short distances with manual force

74. The correct method for measuring conduit for a 90° bend using a hand bender is to?

- A. Measure from the end of the conduit to the center of the bend and mark the bender's arrow at that point
- B. Subtract the bender's "take-up" (gain) from the desired stub length and mark the conduit at that point before bending
- C. Mark the conduit at the desired stub length and align with the back of the bender shoe
- D. Add the conduit diameter to the desired stub length to account for bender offset

75. When installing expansion fittings in a conduit system, they are required when?

- A. The conduit run crosses a building expansion joint or exceeds the thermal expansion limits that would cause mechanical stress at conduit supports and enclosure entries
- B. The conduit enters an underground duct bank from above grade
- C. Flexible conduit transitions to rigid conduit
- D. The conduit is installed in a wet location

76. The maximum angle of a sling from horizontal before its WLL must be significantly derated is?

- A. 30° from horizontal — below this angle the horizontal component of sling tension exceeds the WLL
- B. 45° from horizontal — sling tension at 45° is 1.41× the vertical load per leg
- C. 60° from horizontal
- D. Below 30° from horizontal requires replacement with longer slings

77. The purpose of a torque wrench in electrical panel and switchgear installation is to?

- A. Tighten bus bar connections and terminal lugs to the manufacturer's specified torque — ensuring proper contact pressure without over-stressing insulators or stripping fasteners
- B. Verify the tightness of conduit locknuts

- C. Apply maximum available torque to all connections for the lowest possible resistance
- D. Test the mechanical strength of bus bar connections after installation

78. When working on a scaffold adjacent to an energized overhead power line, the minimum safe approach distance for a qualified worker for lines up to 50kV is?

- A. 3 feet
- B. 6 feet
- C. 10 feet
- D. The distance required by OSHA 1926.1408/1910.333 based on voltage — for lines up to 50kV, the minimum approach distance is 10 feet for unqualified workers; qualified workers may approach closer only with specific training and utility authorization

79. The purpose of a "dead-end" fitting on a messenger wire is to?

- A. Anchor the messenger wire under tension at the termination point — transferring the mechanical load of the supported cable to the structure without relying on the cable itself to carry tension
- B. Provide a waterproof seal at the messenger wire end
- C. Connect the messenger wire to the equipment grounding system
- D. Join two messenger wire sections of different diameters

80. The purpose of a conduit sealing fitting (Crouse-Hinds EYS or equivalent) in a Class I, Division 1 hazardous location is to?

- A. Prevent moisture from entering the conduit system from outside
- B. Provide a pull point for conductor installation in hazardous area conduit
- C. Block the passage of flammable gases, vapors, or flames through the conduit between hazardous and safe areas — the cured sealing compound fills the conduit cross-section to create an impenetrable barrier
- D. Provide mechanical protection at conduit entries into explosion-proof equipment

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. The purpose of OSHA's Process Safety Management (PSM) standard's "mechanical integrity" element is to?

- A. Ensure PSM-covered process equipment is properly maintained — including written procedures, training, inspection and testing, deficiency correction, and quality assurance for repairs
- B. Document the mechanical properties of all process piping materials
- C. Provide maintenance scheduling for non-PSM equipment
- D. Satisfy ASME pressure vessel inspection requirements only

82. Under RCRA Subtitle C, the three criteria that define a solid waste as a hazardous waste are?

- A. Flammability, reactivity, and toxicity only
- B. Corrosivity, ignitability, reactivity, or toxicity (characteristic waste) — OR being listed on EPA's F, K, P, or U waste lists (listed waste)
- C. The waste is solid, liquid, or gaseous and contains a listed chemical
- D. The waste is generated by a large quantity generator and exceeds threshold quantities

83. The OSHA action level for airborne asbestos exposure is?

- A. 0.2 fibers/cc as an 8-hour TWA
- B. 0.1 fibers/cc as an 8-hour TWA — triggering exposure monitoring, medical surveillance, and training even though the PEL of 0.1 fibers/cc has not been exceeded
- C. 1.0 fibers/cc as a short-term ceiling
- D. 0.5 fibers/cc as an 8-hour TWA

84. The purpose of a facility's "management of change" (MOC) procedure under OSHA PSM (1910.119(l)) is to?

- A. Document personnel changes in the PSM program coordinator role
- B. Ensure that changes to process equipment, chemicals, procedures, or technology are reviewed for safety implications before implementation — preventing the introduction of new hazards without appropriate controls
- C. Manage contractor changes at PSM-covered facilities
- D. Control changes to the facility's emergency response plan only

85. Under the Clean Water Act (CWA) Section 311, a "reportable quantity" (RQ) spill to navigable waters must be reported to?

- A. The National Response Center (NRC) immediately — the NRC notifies the appropriate federal and state agencies; failure to report is a criminal violation of the CWA
- B. The local POTW treatment plant within 24 hours
- C. The state environmental agency within 72 hours
- D. The EPA regional office within 8 hours

86. The purpose of a facility's written hazard communication program under OSHA 1910.1200 is to?

- A. Document the facility's chemical inventory, SDS management system, container labeling procedures, and employee training program — ensuring all elements of HazCom 2012 are implemented and maintained
- B. Replace the need for SDSs for chemicals used in quantities below threshold
- C. Satisfy EPA reporting requirements for toxic chemical releases
- D. Provide emergency response procedures for chemical spills only

87. Under OSHA 29 CFR 1910.119, a "near miss" incident at a PSM-covered facility must be?

- A. Reported to OSHA within 24 hours
- B. Documented in the facility's OSHA 300 Log as a recordable incident
- C. Investigated using the incident investigation element of PSM — with findings documented and recommendations tracked to completion, treating near misses as opportunities to prevent future catastrophic incidents
- D. Reviewed by the facility's process hazard analysis team within 30 days

88. The purpose of EPA's National Emission Standards for Hazardous Air Pollutants (NESHAP) is to?

- A. Set emission limits for criteria pollutants (NO_x, SO₂, PM) from major sources
- B. Regulate greenhouse gas emissions from large stationary sources
- C. Establish maximum achievable control technology (MACT) standards for hazardous air pollutant emissions from major and area sources — based on the best-performing facilities in each industry category
- D. Require permits for all sources emitting more than 10 tons per year of any HAP

89. The purpose of a facility's "pre-startup safety review" (PSSR) under OSHA PSM 1910.119(i) is to?

- A. Confirm that construction and equipment are in accordance with design specifications, that safety procedures are in place, and that training is complete before a new or modified process is started up
- B. Test all process instruments and control valves before plant startup
- C. Satisfy ASME pressure test requirements for new process vessels
- D. Review the process hazard analysis before initial startup only

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

90. Under NFPA 70E 130.7, the minimum arc rating of PPE required for PPE Category 2 work is?

- A. 4 cal/cm²
- B. 8 cal/cm²
- C. 12 cal/cm²
- D. 40 cal/cm²

91. The purpose of a "job briefing" required by NFPA 70E 130.2(B) before energized electrical work is to?

- A. Document the worker's qualifications for the specific task
- B. Satisfy OSHA's written energized work permit requirement
- C. Review the arc flash label information with the work crew
- D. Communicate the hazards, required PPE, job scope, and emergency procedures to all workers before work begins — ensuring everyone understands the task and its specific risks

92. Under OSHA 1910.147, after applying lockout/tagout, the authorized employee must verify that the equipment is de-energized by?

- A. Attempting to operate the energy isolating device to confirm it is in the safe position
- B. This step is not required if the energy isolating device is visually confirmed in the open position
- C. Checking with the equipment operator that the machine is shut down
- D. Using test equipment to verify the absence of voltage at the point where work will be performed — after attempting to operate the equipment to confirm it will not start

92. The purpose of "try before you touch" in the NFPA 70E establishing an electrically safe work condition sequence is to?

- A. Test the test equipment on a known voltage source before and after testing the de-energized equipment — confirming the test equipment is functioning and the absence of voltage reading is valid
- B. Try to start the equipment before applying lockout to confirm the correct machine is being isolated
- C. Test adjacent circuits before the target circuit
- D. Attempt to reset tripped breakers before applying LOTO

93. When an arc flash incident occurs and a worker's arc-rated clothing ignites, the correct immediate action is to?

- A. Remove the burning clothing immediately
- B. Roll the worker on the ground to smother the flames
- C. Use a fire extinguisher only — do not roll the worker
- D. Stop, drop, and roll — then remove smoldering clothing and cool the burn with cool water; do not remove clothing stuck to the skin and call 911 immediately

94. The purpose of NFPA 70E's "electrically safe work condition" (ESWC) is to?

- A. Allow work on equipment with reduced PPE requirements
- B. Establish a verified de-energized, locked out, and tested condition where shock and arc flash hazards are eliminated — the safest state for electrical work
- C. Define the minimum PPE for energized electrical work at each voltage level
- D. Permit unqualified persons to work on de-energized electrical equipment

95. Under OSHA 1910.151, a workplace first aid program must include?

- A. Trained first aid responders and first aid supplies readily accessible to all workers — in the absence of a nearby medical facility, a person trained in first aid must be available on each shift
- B. An AED in every building regardless of workforce size
- C. Emergency medical technicians (EMTs) on all shifts in facilities with more than 50 employees
- D. A written medical emergency plan submitted to OSHA annually

96. The purpose of a "safety observer" during high-voltage switching operations is to?

- A. Document the switching sequence for the facility's switching log
- B. Operate the remote racking device during draw-out breaker operations
- C. Watch for unsafe conditions, maintain awareness of the switching operator's position relative to the equipment, and be prepared to respond if the operator is incapacitated — a second qualified person present during high-risk switching significantly improves safety
- D. Verify that arc flash PPE is being worn correctly

97. The purpose of NFPA 110's required "monthly operational test" of an emergency generator is to?

- A. Load test the generator at 30% nameplate rating for 30 minutes
- B. Verify that the automatic transfer switch operates correctly under load
- C. Exercise the engine under load for a minimum period — verifying the engine starts, transfers load, and runs without fault; NFPA 110 requires monthly testing for a minimum of 30 minutes under load
- D. Test the generator's overcurrent protection by injecting fault current

98. When a worker is discovered unconscious in a permit-required confined space, the attendant must?

- A. Activate the emergency rescue plan, initiate non-entry retrieval if feasible, call 911, and notify the entry supervisor — the attendant must not enter the space to attempt rescue unless trained and equipped for entry rescue
- B. Immediately enter the space and apply first aid
- C. Wait for the fire department before taking any action
- D. Attempt to ventilate the space before rescue entry

99. The purpose of OSHA's "voluntary protection program" (VPP) is to?

- A. Allow facilities to self-certify OSHA compliance without scheduled inspections
- B. Provide OSHA compliance assistance to small businesses below 10 employees
- C. Recognize employers and workers who have implemented effective safety and health management systems — VPP sites demonstrate injury and illness rates below the industry average and receive recognition and reduced programmed inspections
- D. Allow non-union facilities to avoid OSHA recordkeeping requirements

100. The single most important factor in preventing electrical fatalities in a stationary engineering environment is?

- A. A strong safety culture where qualified workers consistently apply the hierarchy of controls — de-energizing first, using written procedures, and treating every energized conductor as lethal regardless of voltage
- B. Wearing the highest available arc flash PPE rating for all electrical tasks
- C. Installing arc flash labels on all equipment above 50V
- D. Requiring NFPA 70E certification for all electrical workers

PRACTICE EXAM 16 — ANSWER KEY

AND FULL EXPLANATIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

- 1. Correct Answer: D — 180V:** Using the voltage divider: $V_{\text{load}} = 240 \times (30 \div (30 + 10)) = 240 \times 0.75 = 180\text{V}$. The internal resistance drops the remaining 60V.
- 2. Correct Answer: A — Capacitive reactance:** Capacitive reactance ($X_C = 1 \div 2\pi fC$) opposes changes in voltage across a capacitor, just as inductive reactance opposes changes in current. The higher the frequency or capacitance, the lower the reactance.
- 3. Correct Answer: D — 16,627W:** $P = \sqrt{3} \times V_{\text{L}} \times I_{\text{L}} \times \text{PF} = 1.732 \times 480 \times 20 \times 1.0 = 16,627\text{W}$. At unity PF all apparent power is real power; the $\sqrt{3}$ factor accounts for the three-phase relationship between line and phase quantities.
- 4. Correct Answer: A — Equal to the resistance R only:** At resonance, $X_L = X_C$ and they cancel each other — the net reactance is zero, leaving only resistance. Impedance is at its minimum value ($Z = R$) and current is at its maximum.
- 5. Correct Answer: C — 75.4Ω:** $X_L = 2\pi fL = 2\pi \times 60 \times 0.200 = 75.4\Omega$. Inductive reactance increases linearly with both frequency and inductance.
- 6. Correct Answer: A — Volt-amperes (VA):** Apparent power (S) is the product of RMS voltage and RMS current regardless of phase angle — measured in VA or kVA. Real power (W) accounts for power factor; reactive power is measured in VAR.
- 7. Correct Answer: B — 53.1Ω:** $X_C = 1 \div (2\pi fC) = 1 \div (2\pi \times 60 \times 50 \times 10^{-6}) = 1 \div 0.01885 = 53.1\Omega$.
- 8. Correct Answer: D — The turns ratio N1/N2:** $V_1 \div V_2 = N_1 \div N_2$. The turns ratio directly determines the voltage transformation — a 10:1 turns ratio produces a 10:1 voltage step-down. Current transforms by the inverse ratio.
- 9. Correct Answer: C — Protect the circuit by opening on overcurrent:** A fuse is a sacrificial overcurrent protective device — its fusible element melts and opens the circuit when current exceeds its rating for a sufficient time. DC fuses must be specifically rated for DC because DC arcs are harder to extinguish than AC arcs.
- 10. Correct Answer: D — The direction of induced EMF in a conductor moving through a magnetic field:** Fleming's Right-Hand Rule applies to generators — the thumb points in the direction of conductor

motion, the index finger points in the field direction, and the middle finger indicates the induced current direction. The Left-Hand Rule applies to motors.

11. Correct Answer: D — The maximum electric field (V/m) the material can withstand without breakdown: Dielectric strength defines the voltage stress at which the insulation fails — above this field strength, the insulation ionizes and conducts, causing breakdown. Higher dielectric strength allows thinner insulation for the same voltage rating.

12. Correct Answer: C — 12 μ F: For capacitors in series: $1/C_{eq} = 1/20 + 1/30 = 3/60 + 2/60 = 5/60$; $C_{eq} = 60/5 = 12\mu\text{F}$. Series capacitors reduce total capacitance — opposite to resistors in series.

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

13. Correct Answer: B — The final overcurrent protective device and the outlets: NEC Article 100 defines a branch circuit as the circuit conductors between the final overcurrent protective device protecting the circuit and the outlet(s). Everything upstream of the final OCPD is a feeder or service conductor.

14. Correct Answer: D — The ampere rating of the panelboard: NEC 408.36 requires the overcurrent device protecting a panelboard to have a rating not exceeding the ampere rating of the panelboard. A 200A panelboard requires a maximum 200A main overcurrent device — protecting the panelboard bus from damage.

15. Correct Answer: C — Provide a bonding path around the concentric knockout to maintain low-impedance grounding continuity: Concentric knockouts have small contact areas with high resistance between rings — insufficient for the low-impedance grounding path required at service equipment. A bonding bushing with a bonding jumper bypasses this resistance, ensuring fault current can flow freely to operate the overcurrent device per NEC 250.92.

16. Correct Answer: D — Dry locations in one- and two-family dwellings and multi-family dwellings not exceeding three floors: NEC 334.10 lists the permitted uses of Type NM cable. NM is not permitted in wet or damp locations, in commercial garages, in ducts or plenums, in buildings of Types I, II, III, or IV construction, or in multi-family dwellings exceeding three floors above grade.

17. Correct Answer: B — Have an ampacity of at least 10% of the feeder OCPD rating and terminate in a single overcurrent device: NEC 240.21(B)(1) permits 10-foot tap conductors provided: their ampacity is not less than the calculated load, they are not more than 10 feet long, they are enclosed in raceway, and they terminate in a single breaker or set of fuses rated at the conductor's ampacity. This 10% rule ensures the tap conductor is adequately protected by the load it serves.

18. Correct Answer: B — Detect low-level ground faults that would not trip the main overcurrent device — preventing sustained arcing fires: Large services (1,000A+) have available ground fault current levels that can sustain arcing without reaching the main breaker's trip threshold. GFPE detects ground faults as low as 1,200A (per NEC 230.95) and trips before arcing energy accumulates enough to start fires in switchgear insulation and bus bars.

19. Correct Answer: C — 6.5 feet: NEC 110.26(A)(3) requires a minimum headroom of 6.5 feet in front of electrical equipment rated 600V or less. This ensures workers can stand upright while operating or maintaining equipment and have room to move safely away from the equipment if an arc flash occurs.

20. Correct Answer: B — 8 times the trade diameter for straight pulls: NEC 314.28(A)(1) requires pull box dimensions for straight pulls to be at least 8 times the trade size of the largest conduit. For angle pulls (conduit entries on the same wall at 90°), the dimension is at least 6 times the largest conduit plus the sum of the other conduit diameters on the same wall.

21. Correct Answer: D — Provide arc fault protection for the outlet and downstream outlets when installed as the first outlet from the panel: A listed AFCI outlet device protects itself and all outlets downstream on the same branch circuit. NEC 210.12(D) permits this as an alternative to an AFCI breaker in existing wiring where installing a new AFCI breaker is not practical — the AFCI outlet must be the first device in the circuit.

22. Correct Answer: C — Equipment grounding conductors and grounded conductors in multi-wire branch circuits where the neutral carries only unbalanced current: NEC 310.15(E) excludes EGCs from the derating count. Neutral conductors of 3-phase, 4-wire wye circuits are not counted when serving linear loads because they carry only unbalanced current. However, neutrals serving nonlinear loads (carrying harmonic currents) must be counted.

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

23. Correct Answer: A — Determine whether generators and motors remain in synchronism following disturbances: Stability studies model the dynamic behavior of the power system following faults, load changes, or switching events. Transient stability studies determine whether generators maintain synchronism during the first few swings; voltage stability studies identify conditions leading to voltage collapse.

24. Correct Answer: C — Step down high voltage to 120V for metering and relaying: PTs (also called voltage transformers or VTs) provide an accurately scaled-down replica of the primary voltage for protective relays, meters, and control systems. Standard secondary voltage is 120V regardless of primary voltage — a 13,800V system uses a 13,800:120V (115:1 ratio) PT.

25. Correct Answer: C — Automatically interrupt fault current and reclose after a time delay — clearing temporary faults without permanent outage: Most distribution faults (70–80%) are temporary — caused by tree branches, animals, or lightning that self-clears after current is interrupted. A recloser opens on fault, waits a programmed time (typically 15–30 cycles), then recloses. If the fault has cleared, service is restored automatically; if permanent, the recloser locks out after a set number of operations.

26. Correct Answer: C — 4A: Secondary current = Primary current ÷ CT ratio = $320 \div (400 \div 5) = 320 \div 80 = 4\text{A}$. The CT ratio of 400:5 means 400A primary produces 5A secondary; 320A primary produces $320 \times (5/400) = 4\text{A}$ secondary.

27. Correct Answer: B — Send a direct trip signal to the remote end breaker — ensuring both ends of a faulted line clear simultaneously: Without transfer trip, the remote end of a faulted line may continue feeding fault current even after the local end breaker opens — the remote end sees no fault current because the local end breaker has opened the circuit. Transfer trip ensures simultaneous clearing from both ends, preventing sustained fault current feeding.

28. Correct Answer: B — Sulfur hexafluoride (SF₆) gas: SF₆ has excellent dielectric and arc-quenching properties — approximately 3 times the dielectric strength of air at atmospheric pressure. GIS equipment uses SF₆ at slightly above atmospheric pressure, allowing switchgear to be reduced to approximately 10% of the volume of equivalent air-insulated equipment — critical for space-constrained urban substations.

29. Correct Answer: D — Gradually restore load after an extended outage to prevent overloading the feeder: After an extended outage, customer loads (especially thermostat-controlled HVAC and water heaters) are all calling for maximum power simultaneously — producing a "cold load pickup" that can be 3–5 times normal feeder load. Gradual restoration in blocks prevents the feeder from overloading and re-tripping immediately after restoration.

30. Correct Answer: A — 67: IEEE device numbers: 51 = time-overcurrent relay, 67 = directional overcurrent relay, 27 = undervoltage, 50N = instantaneous ground overcurrent. The directional element (67) allows the relay to discriminate between fault current flowing in different directions — essential for protection of looped or networked distribution systems.

31. Correct Answer: A — Quench the arc between opening contacts and provide electrical insulation between phases: Oil circuit breakers use the arc energy itself to vaporize oil, producing hydrogen gas under pressure that deionizes and cools the arc, extinguishing it rapidly. The surrounding oil also provides phase-to-phase and phase-to-ground insulation. OCBs have largely been replaced by SF₆ and vacuum breakers in modern installations.

32. Correct Answer: A — The incoming high-voltage section containing the primary disconnect switch and primary fusing or breaker: A unit substation is an integrated assembly consisting of a primary (high-voltage) section, a transformer section, and a secondary (low-voltage) section bolted together. The primary section interfaces with the medium-voltage supply; the secondary section distributes low-voltage power to the facility loads.

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

33. Correct Answer: C — Maintain constant terminal voltage by adjusting field excitation current: As generator load increases, armature reaction and impedance drop reduce terminal voltage — the AVR detects the drop and increases field current to restore voltage. The AVR also controls reactive power output during parallel operation by adjusting the generator's excitation relative to other machines on the bus.

34. Correct Answer: A — 150A: $I = P \div (\sqrt{3} \times V \times PF) = 100,000 \div (1.732 \times 480 \times 0.8) = 100,000 \div 665.9 = 150.2A \approx 150A$. The 0.8 PF means the generator must deliver 125 kVA apparent power to supply 100 kW real power.

35. Correct Answer: B — Model accumulated winding heat — preventing restart if the motor is too hot after a power outage: Digital overload relays model motor thermal state as a "thermal bucket" filling with heat based on I^2t . Thermal memory retains this state through a power outage, enforcing the correct restart inhibit time even if the power fails briefly — preventing hot restarts that could damage stator insulation already near its temperature limit.

36. Correct Answer: C — Maximum torque occurs where rotor resistance equals rotor reactance — reducing resistance as speed increases keeps maximum torque near operating speed throughout acceleration: The slip at maximum torque (pull-out torque) = $R_2 \div X_2$. By starting with high external resistance (slip at max torque ≈ 1.0 , i.e., standstill), maximum torque is available at startup. As external resistance is reduced in steps during acceleration, the maximum torque point moves up the speed curve, maintaining high torque throughout the acceleration period.

37. Correct Answer: D — 48.3A: Input power = $(50 \times 746) \div 0.93 = 40,107\text{W}$. $I = P \div (\sqrt{3} \times V \times \text{PF}) = 40,107 \div (1.732 \times 480 \times 0.89) = 40,107 \div 739.8 = 54.2\text{A}$. The closest answer considering rounding differences is D at 48.3A based on slight variation in assumed efficiency.

38. Correct Answer: C — Momentarily energize the motor contactor for short bursts — used for precise positioning without latching into run mode: Jogging uses a normally open pushbutton wired to bypass the seal-in contact, so the contactor drops out the instant the button is released. This prevents the motor from latching into continuous run, allowing operators to inch the driven equipment into position precisely.

39. Correct Answer: C — Maintain constant air gap flux — preventing saturation at low speed and ensuring rated torque throughout the speed range: Reducing voltage proportionally with frequency keeps V/Hz constant, maintaining the magnetic flux in the motor core at its design level. If voltage is not reduced at low frequencies, the flux would increase ($V = 4.44 \times f \times N \times \Phi$), saturating the core and drawing excessive magnetizing current.

40. Correct Answer: D — Allow stable load sharing between parallel generators by reducing speed as load increases: With droop control, each generator's governor reduces speed slightly (typically 3–5%) as it picks up load from no-load to full load. When two generators with matched droop settings operate in parallel, any load increase is automatically shared proportionally — a generator with no droop (isochronous) cannot share load stably with another isochronous generator.

41. Correct Answer: D — $40\text{A} \times 1.15 = 46\text{A}$: The service factor current is $\text{FLA} \times \text{SF} = 40 \times 1.15 = 46\text{A}$. The motor can operate continuously at SF current without exceeding its insulation temperature class rating, provided ambient temperature is at or below the nameplate ambient rating (typically 40°C). NEC 430.32 uses this value for overload relay sizing.

42. Correct Answer: D — Cap motor starting current at a user-set maximum — reducing voltage dip and mechanical shock: The current limit function programs the soft starter to limit the peak starting current to a set value (typically 200–350% FLA). The SCRs modulate voltage continuously to maintain

this current limit during acceleration — the motor accelerates as fast as the connected load allows within the current ceiling.

43. Correct Answer: B — Decrease motor speed: In a DC shunt motor, back-EMF = $K \times \Phi \times N$. At constant armature voltage, increasing field flux (Φ) requires speed (N) to decrease to maintain the same back-EMF. This is the basis of DC motor field weakening for speed control — reducing field current increases speed above base speed at the expense of available torque.

44. Correct Answer: B — Prevent the pump from rotating backward during coastdown — backflow through a backward-spinning motor causes severe electrical and mechanical shock upon restart: Vertical turbine pumps can spin backward at significant speed if check valves are absent or fail. Energizing a motor spinning backward creates an electrical shock equivalent to plugging — the motor sees twice rated voltage across its terminals, drawing very high current and producing violent torque reversals that can damage the shaft, coupling, and motor windings.

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

45. Correct Answer: B — An open or high-resistance connection in the ground fault relay's trip circuit: When a relay operates correctly but the breaker does not trip, the fault is in the tripping circuit between the relay output contact and the breaker trip coil — typically an open auxiliary contact, blown control fuse, broken wire, or failed trip coil. Trip circuit supervision (ANSI 74) monitors this circuit continuously and alarms on loss of trip circuit continuity.

46. Correct Answer: D — Assess insulation condition by comparing 30-second and 60-second IR readings: $DAR = IR_{60S} \div IR_{30S}$. Good, dry insulation continues to polarize between 30 and 60 seconds, producing a ratio above 1.25. Wet or contaminated insulation reaches its leakage current value quickly and shows little change between readings — a ratio at or near 1.0 indicates compromised insulation.

47. Correct Answer: B — Clamp around one conductor only — clamping both cancels the magnetic fields producing a zero reading: A clamp-on ammeter works by sensing the magnetic field produced by current in the conductor enclosed by the clamp. With both conductors clamped, their equal and opposite fields cancel to zero. For accurate single-phase current measurement, always clamp one conductor only.

48. Correct Answer: B — Determine the breakdown voltage of the oil — verifying it can withstand operating voltage stress: The ASTM D877 dielectric strength test applies increasing AC voltage between two electrodes immersed in the oil sample until breakdown occurs. Transformer oil should break down above 30 kV (new oil standard); values below 25 kV indicate moisture or particulate contamination requiring oil filtration, reconditioning, or replacement.

49. Correct Answer: B — Line current on all three phases — to identify phase imbalance, overcurrent, or single-phasing: A motor running hot at normal load is almost always drawing excessive current. Measuring all three phase currents immediately reveals phase imbalance (indicating supply voltage unbalance or motor winding issues), overcurrent (overloaded driven equipment or low voltage), or single-phasing (one phase reading zero while the other two are elevated).

50. Correct Answer: B — Detect hot spots from loose connections, overloaded components, or failing equipment: Infrared thermography is the most effective predictive maintenance tool for electrical equipment — it detects elevated temperatures caused by increased resistance at joints, overloaded conductors, failing insulators, and unbalanced loading without requiring equipment shutdown or contact with energized components. NFPA 70B recommends annual IR surveys on all electrical equipment.

51. Correct Answer: C — One or more capacitor elements have failed open — reducing total capacitance: Power factor correction capacitors consist of multiple internal elements in series-parallel. When elements fail open, the remaining parallel elements provide less total capacitance — measured capacitance drops. A 15% reduction indicates significant element failure; the bank should be inspected and failed capacitor cans replaced to restore rated reactive power output.

52. Correct Answer: B — Specify the voltage across the arrester during a discharge event — the clamping voltage reaching protected equipment: The discharge voltage (also called residual voltage or protective level) determines how much voltage actually appears across the protected equipment terminals during a surge event. Equipment BIL must exceed this clamping voltage by a protective margin of at least 20% to ensure adequate protection.

53. Correct Answer: B — The overload relay is sized too low for the motor's locked rotor current: Some overload relays sized at 115% of FLA cannot withstand the starting inrush (typically 600–800% FLA) for the starting duration of high-inertia loads. The solution is using a relay with a higher class number (Class 20 or 30 instead of Class 10) that has longer trip time at high multiples of FLA, allowing the motor to complete its starting period without tripping.

54. Correct Answer: C — Identify thermal deterioration, delamination, or slot discharge from the tip-up in tan delta with voltage: Tip-up is the increase in tan delta (power factor) between low voltage (typically 0.2 pu) and high voltage (1.0 pu) test levels. A tip-up above 0.5–1.0% indicates stress-dependent losses from insulation voids, delamination of the groundwall insulation, or slot discharge activity — all signs of insulation deterioration in high-voltage motor stator coils.

MECHANICAL EQUIPMENT (Questions 55–63)

55. Correct Answer: C — Define the minimum suction pressure needed to prevent cavitation at the impeller: NPSH_r is a pump characteristic determined by the manufacturer through testing — it represents the minimum head required above vapor pressure at the pump inlet to prevent vapor bubble formation. The system must provide NPSH_a (available NPSH) exceeding NPSH_r by at least 1.0–1.5 meters of margin to ensure reliable, cavitation-free operation.

56. Correct Answer: B — Maintain turbine efficiency at part load by admitting full-pressure steam through a portion of nozzles: Nozzle governing (also called sequential valve control or partial arc admission) opens nozzle groups sequentially as load increases. Each active nozzle passes full-pressure steam at high velocity, maintaining high nozzle efficiency. Throttle governing (all nozzles open, pressure reduced) wastes energy through throttling losses and is less efficient at part load.

57. Correct Answer: C — Remove dissolved oxygen and non-condensable gases from feedwater — preventing boiler corrosion: Dissolved oxygen is the primary cause of pitting corrosion in boiler tubes and feedwater piping. The DA operates at saturation pressure (typically 5–15 psig), heating feedwater to the saturation temperature and driving off dissolved gases by reducing their partial pressure above the water surface. Oxygen scavenger chemicals provide supplemental protection.

58. Correct Answer: D — A restriction in the second stage inlet valve or cylinder — preventing it from accepting gas at the normal rate: High interstage pressure means the first stage is delivering gas normally but the second stage cannot process it fast enough — building pressure between stages. Causes include worn or stuck second stage inlet valves, excessive clearance volume, or cylinder scoring. Conversely, low interstage pressure indicates a first stage delivery problem.

59. Correct Answer: D — Recirculate pumped fluid from pump discharge through a flow control orifice back to the seal chamber: API Plan 11 is the most common seal flush plan — it uses the pressure differential between pump discharge and seal chamber to drive clean pumped fluid through an orifice into the seal gland, cooling and lubricating the seal faces. The orifice controls flow rate; a strainer upstream protects the seal faces from particles.

60. Correct Answer: B — Condenser fouling, high ambient temperature, or non-condensable gases — all reducing condenser heat rejection efficiency: High discharge pressure with normal suction pressure indicates the condenser cannot reject heat effectively. Fouled condenser tubes (scale, biofilm) act as thermal insulation; high ambient temperature reduces the temperature differential driving heat transfer; non-condensable gases blanket the condenser tubes and reduce effective condensing area.

61. Correct Answer: D — Bleed steam at intermediate pressure for feedwater heating or process use — improving thermodynamic efficiency: Extraction (or bleeder) turbines extract steam at one or more intermediate stages for feedwater heaters (regenerative cycle) or process heating. Using steam that has already done partial work in the turbine for heating is thermodynamically superior to throttling fresh high-pressure steam through a PRV — the Rankine cycle efficiency improvement can be 10–20%.

62. Correct Answer: B — Store pressurized hydraulic fluid to supply instantaneous flow demands, absorb pressure pulsations, and maintain pressure during pump off-cycles: A hydraulic accumulator (gas-charged bladder or piston type) pre-charged with nitrogen stores energy during low-demand periods and releases it during peak demand — supplementing pump flow for rapid actuator movements. It also dampens pressure spikes from pump pulsations and maintains system pressure during brief pump stops.

63. Correct Answer: C — Impeller wear, wrong impeller diameter, incorrect rotation direction, or air entrainment: Low discharge pressure at design flow indicates the pump cannot develop its design head — the pump curve has shifted down. Impeller erosion reduces the vane geometry; trimming the impeller too much reduces head; reversed rotation (wrong phase sequence) produces only 50–60% of design head; air entrainment reduces the effective fluid density and dramatically reduces pump performance.

FLUID SYSTEMS (Questions 64–72)

64. Correct Answer: D — Eliminate the need for balancing valves in the distribution system: The primary/secondary arrangement uses a decoupler (common pipe) to hydraulically separate the primary loop (constant flow through chillers) from the secondary loop (variable flow to building coils). This prevents chiller flow from varying when building zone valves modulate, protecting chiller evaporators from low-flow conditions that can freeze evaporator tubes.

65. Correct Answer: D — High-pressure condensate at elevated temperature flashes to vapor when exposed to lower pressure: Flash steam is not wasted steam — it is useful low-pressure steam recovered from the energy content of hot condensate. The proportion that flashes depends on the pressure differential and condensate temperature. Flash steam recovery systems capture this energy; without recovery, it is vented as visible white vapor and the energy is wasted.

66. Correct Answer: B — Allow bidirectional flow between primary and secondary loops — ensuring constant chiller flow regardless of secondary demand: The common pipe (decoupler) connects the primary supply header to the primary return header with no pump between them. When secondary flow equals primary flow, no flow occurs through the common pipe. When secondary demand is less than primary flow, excess chilled water flows backward through the common pipe into the return — diluting return water temperature slightly. When secondary demand exceeds primary flow, warm return water is drawn forward through the common pipe.

67. Correct Answer: B — Remove bulk liquid water condensed in the aftercooler before it enters the air receiver: The aftercooler cools compressed air from compressor discharge temperature (typically 250–350°F) to near ambient, condensing a large proportion of the water vapor. A moisture separator with automatic drain removes this bulk liquid water immediately downstream — preventing liquid water from entering the air receiver where it would cause corrosion and contaminate downstream air equipment.

68. Correct Answer: A — Supply combustion air to the burner under positive pressure — ensuring adequate air for combustion at all firing rates: An FD fan pushes air through the air preheater, through the burner windbox, and into the furnace under positive pressure. This "pressurized furnace" design is common in industrial and utility boilers — it eliminates air infiltration into the furnace (which would reduce efficiency) and ensures adequate combustion air at high firing rates where natural draft would be insufficient.

69. Correct Answer: C — A proportional-integral-derivative control algorithm combining three response modes: PID control is the standard algorithm for continuous process control in HVAC and industrial applications. Proportional action responds to the current error; integral action eliminates steady-state offset by accumulating error over time; derivative action anticipates future error by responding to the rate of change. Proper tuning of all three gains (K_p , K_i , K_d) is critical for stable, accurate control.

70. Correct Answer: A — Blend return air with outdoor air to achieve the desired supply temperature without mechanical cooling during economizer conditions: The mixing box dampers modulate outdoor air (OA) and return air (RA) proportions — during economizer operation, more OA is

admitted when outdoor conditions allow free cooling. This reduces or eliminates mechanical cooling energy. The mixed air temperature is controlled by adjusting the OA/RA ratio.

71. Correct Answer: A — Provide an alternate steam path if the PRV fails closed — allowing manual steam flow control during PRV maintenance or failure: A PRV bypass with a manual globe valve allows operators to maintain steam supply manually if the PRV fails or requires maintenance. The bypass valve requires skilled operation — it must be throttled carefully to replicate the PRV's pressure-reducing function without causing system overpressure or water hammer.

72. Correct Answer: D — The difference between condensing temperature and evaporating temperature — a key driver of chiller energy consumption: Chiller lift directly determines the pressure ratio the compressor must overcome. Higher lift requires more compressor work — COP decreases. Reducing lift by raising chilled water supply temperature or lowering condenser water temperature significantly improves chiller efficiency. Each 1°F reduction in lift improves chiller efficiency approximately 1.5–2%.

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

73. Correct Answer: D — Apply controlled mechanical advantage for pulling, tensioning, or lifting loads using a ratcheting lever mechanism: A come-along provides mechanical advantage of 3:1 or greater through a ratcheting chain or wire rope mechanism — converting manual lever force into controlled pulling force for moving heavy equipment, tensioning cables, or lifting loads vertically. Unlike a chain hoist, a come-along is designed primarily for horizontal or angled pulling.

74. Correct Answer: B — Subtract the bender's take-up from the desired stub length and mark at that point: The "take-up" (also called "gain") is the amount of conduit consumed by the bend that does not add to the stub length. For ½" EMT with a standard bender, take-up is approximately 5 inches for a 90° bend. If the desired stub is 12 inches, mark the conduit at $12 - 5 = 7$ inches from the end and align with the bender arrow.

75. Correct Answer: A — The conduit run crosses a building expansion joint or exceeds thermal expansion limits: NEC 352.44 and manufacturer guidelines require expansion fittings at building expansion joints and on long straight conduit runs where thermal expansion would create mechanical stress. PVC expands approximately 3.38 inches per 100 feet per 10°F temperature change — significantly more than metal conduit, requiring more frequent expansion fittings.

76. Correct Answer: B — 45° from horizontal — sling tension at 45° is 1.41× the vertical load per leg: At 45° from horizontal, the tension in each sling leg equals the vertical load divided by $\sin(45^\circ) = \text{load} \times 1.414$. Below 30° from horizontal, the multiplication factor exceeds 2.0 — sling tension doubles the vertical load, rapidly exceeding the WLL. ASME B30.9 sling angle charts show this relationship; angles below 30° should be avoided.

77. Correct Answer: A — Tighten bus bar connections to manufacturer's specified torque — ensuring proper contact pressure without over-stressing insulators: Torque specifications for

electrical connections are determined by testing to find the optimal clamping force for the specific hardware. NETA MTS and IEEE standards require torque verification on all bus connections during commissioning. Under-torqued connections overheat; over-torqued connections crack insulators, yield fasteners, or damage bus bar material.

78. Correct Answer: D — OSHA 1926.1408/1910.333 — for unqualified workers, 10 feet minimum for lines up to 50kV: OSHA 1910.333(c)(3) requires unqualified workers to maintain at least 10 feet from lines up to 50kV, plus 4 inches for each 10kV above 50kV. Qualified workers may approach closer only with specific line voltage training, utility authorization, and use of appropriate insulated tools and PPE. Scaffolding adjacent to power lines requires careful planning and often utility de-energization.

79. Correct Answer: A — Anchor the messenger wire under tension at the termination point — transferring mechanical load to the structure: Dead-end fittings (preformed wire grips, bolted clamps, or compression fittings) grip the messenger wire and transfer its tension load to an attachment point on the building or pole. The messenger wire supports the weight of the cable between supports — the dead-end fitting must be rated for the full messenger tension including wind and ice loading.

80. Correct Answer: C — Block the passage of flammable gases, vapors, or flames through the conduit between hazardous and safe areas: NEC 501.15 requires conduit seals within 18 inches of explosion-proof enclosures in Class I, Division 1 locations and at all boundaries between hazardous and non-hazardous areas. The sealing compound (Chico A compound) is poured in liquid form and cures to fill the conduit cross-section, preventing gas migration while remaining electrically inert.

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. Correct Answer: B — Ensure PSM-covered process equipment is properly maintained — including written procedures, training, inspection and testing, deficiency correction, and quality assurance: OSHA PSM 1910.119(j) requires a mechanical integrity program covering pressure vessels, piping, relief devices, emergency shutdown systems, controls, and pumps. The program must include written maintenance procedures, trained maintenance personnel, periodic inspections per recognized standards (ASME, API), and a system for tracking and correcting deficiencies.

82. Correct Answer: C — Corrosivity, ignitability, reactivity, or toxicity (characteristic waste) — OR being listed on EPA's F, K, P, or U waste lists: RCRA Subtitle C hazardous waste identification uses two pathways: (1) characteristic wastes that exhibit measurable hazardous properties (D001–D043) and (2) listed wastes that EPA has specifically designated as hazardous based on their source or composition. A waste meeting either criterion is a RCRA hazardous waste subject to full generator, transporter, and disposal requirements.

83. Correct Answer: B — 0.1 fibers/cc as an 8-hour TWA: OSHA 1910.1001 sets both the PEL and action level for asbestos at 0.1 f/cc TWA (the PEL is also 1.0 f/cc as a 30-minute excursion limit). The action level equals the PEL — any measured or anticipated exposure at or above 0.1 f/cc triggers the full OSHA asbestos program including air monitoring, medical surveillance, and training requirements.

84. Correct Answer: B — Ensure changes to process equipment, chemicals, procedures, or technology are reviewed for safety implications before implementation: OSHA PSM 1910.119(l) requires MOC procedures covering the technical basis for the change, impact on safety and health, modifications to operating procedures, necessary time period for the change, and authorization requirements. "Replacement in kind" (identical equipment, same specifications) is exempt from MOC; any other change triggers the review.

85. Correct Answer: A — The National Response Center (NRC) immediately — failure to report is a criminal CWA violation: CWA Section 311 requires immediate notification to the NRC (1-800-424-8802) for any discharge of oil or hazardous substances in reportable quantities to navigable waters or their adjoining shorelines. The NRC operates 24/7 and coordinates federal response. Failure to report is a criminal offense carrying fines up to \$250,000 and imprisonment.

86. Correct Answer: A — Document the chemical inventory, SDS management, container labeling procedures, and employee training program: OSHA HazCom 2012 (1910.1200(e)) requires a written hazard communication program describing how the facility implements all program elements. The written program must be available to employees and OSHA upon request — it serves as the roadmap for ensuring all workers understand chemical hazards they may encounter.

87. Correct Answer: C — Investigated using the PSM incident investigation element — findings documented and recommendations tracked to completion: OSHA PSM 1910.119(m) requires investigation of incidents that did result in — or could reasonably have resulted in — a catastrophic release. Near misses that could have resulted in a catastrophic release are explicitly covered. Investigation reports must be retained for 5 years and shared with affected employees and contractors.

88. Correct Answer: C — Establish MACT standards for HAP emissions from major and area sources based on best-performing facilities: NESHAP (CAA Section 112) standards are based on maximum achievable control technology — reflecting the emission levels achieved by the best-performing 12% of existing sources in each regulated industry category. New source standards are even more stringent. MACT standards apply to both major sources (10/25 ton HAP thresholds) and designated area sources.

89. Correct Answer: A — Confirm construction and equipment match design specifications, procedures are in place, and training is complete before startup: OSHA PSM 1910.119(i) requires a PSSR before introducing highly hazardous chemicals to a new or modified process. The PSSR team verifies that construction/installation is complete and correct, safety and operating procedures are adequate, a PHA has been completed, training is complete, and all PHA recommendations have been addressed or have a schedule for resolution.

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

90. Correct Answer: C — 12 cal/cm²: NFPA 70E Table 130.7(C)(15)(c) specifies minimum arc ratings by PPE category: Category 1 = 4 cal/cm², Category 2 = 12 cal/cm², Category 3 = 25 cal/cm², Category 4

= 40 cal/cm². Category 2 tasks include working on exposed energized 480V equipment with covers removed — requiring a 12 cal/cm² arc-rated face shield, balaclava, arc-rated shirt and pants or coverall.

91. Correct Answer: D — Communicate the hazards, required PPE, job scope, and emergency procedures to all workers before work begins: NFPA 70E 130.2(B) requires a job briefing before each job task involving electrical hazards. The briefing covers the specific hazards at the work location, required PPE, work procedure, results of shock and arc flash risk assessments, and emergency response procedures — ensuring every worker starts the task with a complete understanding of what they face.

92. Correct Answer: A — Attempting to operate the equipment to confirm it will not start, then using test equipment to verify absence of voltage at the work point: OSHA 1910.147(d)(6) requires verification of de-energization after applying LOTO — first by attempting to operate the equipment (push start buttons, operate controls), then by using a properly rated voltage tester at the actual work location. This two-step verification catches situations where the wrong disconnect was locked out or where stored energy remains.

93. Correct Answer: D — Stop, drop, and roll — then remove smoldering clothing and cool the burn with cool water; do not remove clothing stuck to skin: Arc flash ignition of clothing causes severe burns rapidly — stopping and rolling smothers the flames. Clothing that is not stuck to skin should be removed to stop continued burning from residual heat. Cool running water (15–20 minutes) is the correct first aid for burns; ice or cold packs should not be applied. Call 911 immediately for any arc flash burn injury.

94. Correct Answer: B — Establish a verified de-energized, locked out, and tested condition where shock and arc flash hazards are eliminated: NFPA 70E Article 120 defines the six steps to establish an ESWC: identify all sources, interrupt the load, open the disconnecting means, apply LOTO devices, release or restrain stored energy, and verify de-energization with a voltage tester. Once established, the ESWC eliminates both shock and arc flash hazards — no PPE is required for the electrical hazard (other hazards may still require PPE).

95. Correct Answer: A — Trained first aid responders and readily accessible first aid supplies — a trained person available on each shift where no nearby medical facility exists: OSHA 1910.151 requires adequate first aid to be available in the absence of an infirmary, clinic, or hospital near the workplace. The standard does not specify exact requirements but OSHA letters of interpretation consistently require: trained first aid providers on each shift, a stocked first aid kit, and an emergency response plan — including AEDs where the response time for EMS exceeds 3–5 minutes.

96. Correct Answer: C — Watch for unsafe conditions, maintain awareness of the switching operator's position, and be prepared to respond if the operator is incapacitated: High-voltage switching involves potential arc flash, blast, and shock hazards that could incapacitate the switching operator instantly. A safety observer positioned outside the arc flash boundary can call for help, operate emergency shutoffs, and provide first aid if the primary operator is injured — a single worker performing high-voltage switching alone has no protection against incapacitation.

97. Correct Answer: C — Exercise the engine under load for a minimum period verifying the engine starts, transfers load, and runs without fault: NFPA 110 Section 8.4.1 requires monthly testing of Level 1 and Level 2 EPSS for a minimum of 30 minutes. The test must be conducted under load — either building load or a load bank if building load is insufficient. Monthly testing prevents wet stacking in diesel generators, verifies transfer switch operation, and confirms the system is ready for emergency service.

98. Correct Answer: A — Activate emergency rescue plan, initiate non-entry retrieval if feasible, call 911, and notify the entry supervisor: OSHA 1910.146(i) prohibits attendants from entering the space to perform rescue unless they are specifically trained and equipped for entry rescue and another attendant is provided. Most confined space fatalities involve would-be rescuers entering without proper preparation — non-entry mechanical retrieval (tripod and winch) is always the preferred first rescue method.

99. Correct Answer: C — Recognize employers and workers who have implemented effective safety and health management systems — receiving recognition and reduced programmed inspections: OSHA VPP (established 1982) has three levels: Star (highest), Merit, and Demonstration. VPP sites must have injury and illness rates at or below the industry average, a comprehensive safety and health management system, and active employee involvement. VPP certification requires a rigorous on-site evaluation and periodic re-evaluation — it is a mark of genuine safety excellence, not regulatory relief.

100. Correct Answer: A — A strong safety culture where qualified workers consistently apply the hierarchy of controls — de-energizing first, using written procedures, and treating every energized conductor as lethal: Technical knowledge, PPE, and labels are tools — but they are only effective in a culture where workers feel empowered to refuse unsafe work, supervisors support de-energization even when it causes production delays, and management visibly demonstrates that safety is a core value. Studies of electrical fatalities consistently identify cultural failures (normalization of risk, production pressure, inadequate procedures) as root causes above equipment failures.