

PRACTICE EXAM 12: STATIONARY ENGINEER (ELECTRIC) SIMULATION — 100 QUESTIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. The total voltage in a series circuit with three resistors of 10Ω , 20Ω , and 30Ω carrying $2A$ is?

- A. 30V
- B. 120V
- C. 60V
- D. 240V

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

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

3. A 120V circuit has a resistance of 24Ω . The power dissipated is?

- A. 5W
- B. 600W

C. 2,880W

D. 240W

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

A. Zero

B. The resistance R only — inductive and capacitive reactances cancel

C. The sum of $R + X_L + X_C$

D. X_L only

5. The phase relationship between voltage and current in a purely resistive AC circuit is?

A. Current leads voltage by 45°

B. Voltage leads current by 90°

C. Current lags voltage by 90°

D. Voltage and current are in phase — 0° phase angle

6. Which of the following best describes the function of a rectifier in an electrical system?

A. Converts DC voltage to a higher DC voltage

B. Converts AC voltage to a lower AC voltage

C. Converts AC voltage to DC voltage

D. Converts DC voltage to AC voltage

7. The apparent power in a single-phase AC circuit with 240V and 15A at 0.80 power factor is?

A. 2,880 VA

- B. 192 VA
- C. 2,304 VA
- D. 3,600 VA

8. Mutual inductance between two coils refers to?

- A. The property by which a changing current in one coil induces an EMF in a nearby coil through their shared magnetic flux
- B. The total inductance of two coils connected in series
- C. The opposition to current flow in both coils simultaneously
- D. The magnetic shielding effect between two adjacent coils

9. A 480V, 60 Hz transformer has a core flux that reaches its peak value at the moment when the applied voltage is?

- A. At its negative peak value
- B. Passing through zero — because flux is 90° behind voltage in a transformer
- C. At its positive peak value
- D. At its RMS value

10. In an AC circuit, reactive power (Q) is measured in?

- A. Watts (W)
- B. Volt-amperes (VA)
- C. Kilowatts (kW)
- D. Volt-amperes reactive (VAR)

11. A 3-phase, 480V motor has a full-load efficiency of 90% and draws 50A at 0.88 power factor. The output horsepower is approximately?

- A. 40 HP
- B. 28 HP
- C. 50 HP
- D. 43 HP

12. The skin effect in AC conductors causes?

- A. Reduced conductor resistance at higher frequencies
- B. Current to concentrate near the outer surface of the conductor at higher frequencies — increasing effective resistance compared to DC resistance
- C. Uniform current distribution across the conductor cross-section at all frequencies
- D. Increased conductor insulation resistance at higher frequencies

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

13. The NEC definition of a "feeder" is?

- A. The conductors from the service point to the first overcurrent device
- B. All circuit conductors between the service equipment (or source of a separately derived system) and the final branch circuit overcurrent protective device
- C. The conductors from a panelboard to the final outlet
- D. Any conductor larger than 4 AWG supplying multiple branch circuits

14. Which of the following best describes a Class RK1 current-limiting fuse?

- A. A rejection-type fuse with very fast clearing characteristics that limits the peak let-through current and I^2t energy during high fault currents — providing superior equipment protection
- B. A standard time-delay fuse rated for motor starting
- C. A fuse designed for service entrance protection only
- D. A non-current-limiting fuse with standard inverse time characteristics

15. The purpose of a separate equipment grounding conductor (EGC) run with the circuit conductors is to?

- A. Provide a low-impedance fault current return path that causes the overcurrent device to operate quickly during a ground fault — limiting fault duration and preventing sustained arcing
- B. Serve as an emergency neutral conductor if the neutral fails
- C. Provide a return path for normal load current
- D. Supplement the conduit system's grounding capability for high-fault-current applications

16. NEC Section 240.4(D) limits the overcurrent protection for 14 AWG copper conductors to a maximum of?

- A. 20A
- B. 15A
- C. 25A
- D. 30A

17. Type XHHW-2 conductor insulation is rated for?

- A. 60°C dry locations only

- B. 75°C wet and 90°C dry locations
- C. 75°C dry and wet locations
- D. 90°C in both wet and dry locations

18. Which of the following is the correct procedure for installing conductors in a conduit that already contains other conductors?

- A. Any additional conductors may be pulled in as long as the conduit is not full
- B. Verify that the additional conductors do not exceed the conduit's fill capacity per NEC Chapter 9 Tables, apply conductor derating if total current-carrying conductors exceed three, then pull all conductors simultaneously if possible
- C. Only one additional conductor may be added to any existing conduit installation
- D. Remove all existing conductors, install all conductors together, and re-pull as a group

19. The purpose of a listed "listed combination motor controller" (also called a manual motor protector or MMP) is to?

- A. Provide both motor overload and short circuit protection in a single device — replacing the need for a separate motor starter and branch circuit fuse or breaker in some applications
- B. Provide automatic reduced-voltage starting for large motors
- C. Monitor motor speed and trip on overspeed conditions
- D. Replace the motor disconnect means in a motor branch circuit

20. In a service entrance installation, the main bonding jumper (MBJ) connects?

- A. The grounding electrode to the neutral bus
- B. The service phase conductors to the grounding electrode conductor
- C. The equipment grounding bus to the grounding electrode conductor

D. The neutral bus (grounded conductor) to the equipment grounding bus and enclosure at the service disconnect — establishing the system ground reference point

21. A 277V, 20A fluorescent lighting circuit uses 12 AWG THWN conductors in EMT. The maximum one-way circuit length before voltage drop exceeds 3% is approximately?

A. 350 feet

B. 175 feet

C. 450 feet

D. 230 feet

22. The NEC requires working clearance in front of electrical equipment operating at 0–150V to ground (Condition 2) to be a minimum of?

A. 2.5 feet

B. 1.5 feet

C. 4 feet

D. 3.5 feet

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

23. A delta-connected transformer bank with one transformer removed (open delta or V-V connection) can supply three-phase loads at what percentage of the original closed delta bank rating?

A. 57.7% — the open delta connection delivers only $1/\sqrt{3}$ of the closed delta bank kVA capacity despite using only $2/3$ of the transformers

B. 66.7% — proportional to the two remaining transformers

C. 75% — with a 25% derating for unbalanced operation

D. 50% — one transformer removed reduces capacity by half

24. The purpose of a power system stabilizer (PSS) added to a generator's AVR is to?

- A. Prevent generator overvoltage during load rejection
- B. Damp low-frequency power oscillations between generators by introducing a supplementary stabilizing signal into the excitation system — improving dynamic stability of interconnected power systems
- C. Regulate the generator's reactive power output independently of terminal voltage
- D. Provide backup voltage regulation if the main AVR fails

25. In a substation, the purpose of a potential transformer (PT or VT) is to?

- A. Step down high system voltage to a safe, standardized level (typically 120V) for metering, protection relays, and instrumentation — while providing galvanic isolation from the high-voltage circuit
- B. Measure current in high-voltage circuits for metering purposes
- C. Step up low voltage for relay testing purposes
- D. Provide a low-impedance voltage source for relay testing

26. Which protection scheme is used to protect a bus section against internal faults in a substation?

- A. Distance protection (ANSI 21) with multiple zones
- B. Overcurrent protection (ANSI 51) on each feeder
- C. Bus differential protection (ANSI 87B) — comparing the sum of all currents flowing into the bus; any difference indicates an internal bus fault
- D. Directional overcurrent protection (ANSI 67) on each source

27. The purpose of an automatic transfer switch (ATS) in a facility power system is to?

- A. Transfer loads between two utility feeders only — emergency generators are not compatible with ATS
- B. Provide soft-starting capability for large motor loads during utility outages

C. Regulate voltage during the transition between utility and emergency power

D. Automatically detect a utility power failure, signal the emergency generator to start, and transfer the connected loads from the utility source to the generator when it reaches acceptable voltage and frequency — then retransfer when utility power is restored

28. A medium-voltage cable splice must be made using stress control materials because?

A. Standard electrical tape provides insufficient mechanical strength at splice points

B. The geometric discontinuity at the splice point concentrates electrical stress — stress control tape or factory-molded stress cones redistribute the electric field to prevent insulation breakdown at the cable termination or splice

C. The splice must be rated for the full fault current of the circuit

D. Standard insulating materials are not rated for medium-voltage applications

29. In a large industrial facility, harmonic currents from VFDs cause overheating in a delta-wye transformer. The primary reason is?

A. The VFD harmonic currents saturate the transformer core continuously

B. Harmonic currents increase the transformer's no-load losses proportionally

C. The delta winding provides a circulating path for triplen harmonics (3rd, 9th, 15th) — preventing them from reaching the supply system but causing additional winding heating within the delta

D. The wye secondary cannot supply harmonic current to non-linear loads

29. In a large industrial facility, harmonic currents from VFDs cause overheating in a delta-wye transformer. The primary reason delta-connected windings experience additional heating from harmonics is?

A. Harmonic currents increase transformer iron core losses only

B. Harmonic currents increase the transformer's magnetizing current

C. Harmonic currents create additional copper losses (I^2R) in the windings — higher-frequency harmonics also increase eddy current losses in the core and windings proportional to the square of the harmonic order

D. The wye winding traps all harmonic currents

30. The sequence of events in an automatic reclosing cycle on a distribution feeder after a fault occurs is?

A. Trip — lockout — manual reclose

B. Trip — reclose attempt 1 — reclose attempt 2 — reclose attempt 3 — lockout if fault persists

C. Trip — 30-second delay — reclose — lockout

D. Instantaneous trip — dead time delay — reclose — if fault persists, trip again with time-delay — additional reclose attempts — final lockout after programmed number of unsuccessful reclosures

31. In power system analysis, a "per-unit" value is?

A. A value expressed as a ratio of the actual quantity to a chosen base quantity of the same dimension — simplifying calculations by eliminating the need to track actual voltages and currents across transformers

B. A measurement in SI units only

C. A value normalized to the rated current of the equipment

D. A value expressed per mile of transmission line length

32. The purpose of lightning shielding wires (overhead ground wires) on a transmission line is to?

A. Provide a return current path for unbalanced loads on the transmission system

B. Intercept lightning strokes before they contact the phase conductors — directing the lightning current to ground through the tower structure and grounding system rather than through the phase conductors and equipment

C. Reduce the transmission line's inductive reactance

D. Provide a communication path between substations

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

33. A generator's AVR (Automatic Voltage Regulator) senses terminal voltage and adjusts field current. When a large load is suddenly applied, the AVR responds by?

- A. Reducing field current to prevent overvoltage from the load current's reactive demand
- B. Increasing field current to restore terminal voltage — the load's reactive current demand causes voltage to drop, and the AVR increases excitation to compensate
- C. Reducing prime mover speed to limit current
- D. Opening the generator breaker to prevent voltage collapse

34. The purpose of a motor's starting winding in a single-phase induction motor is to?

- A. Provide continuous running torque at full speed
- B. Supply reactive power to the motor during operation
- C. Create a phase-shifted magnetic flux to produce starting torque — single-phase induction motors have no inherent starting torque without an auxiliary starting winding or other starting mechanism
- D. Reduce motor current during the running condition

35. In an electric arc furnace (EAF) installation, the electrode regulation system controls?

- A. The furnace temperature by adjusting coolant flow
- B. Electrode position to maintain a constant arc current (or power) setpoint — the electrode moves up or down to maintain the desired arc gap as the scrap melts and the furnace geometry changes
- C. The furnace tilting mechanism for tapping molten steel
- D. The furnace transformer tap position for voltage control

36. The purpose of a motor's centrifugal switch (in single-phase induction motors) is to?

- A. Disconnect the starting winding from the circuit when the motor reaches approximately 75–80% of synchronous speed — the starting winding is only needed for starting and would overheat if left continuously energized
- B. Trip the motor on overspeed
- C. Disconnect the run capacitor at low speeds
- D. Connect the starting capacitor when the motor reaches full speed

37. In a three-phase squirrel cage induction motor, the rotor bars are typically skewed (twisted slightly) to?

- A. Increase the motor's starting torque above the theoretical maximum
- B. Reduce magnetic noise and torque pulsations by ensuring rotor bars pass smoothly through the stator magnetic field rather than all simultaneously aligning with stator slots — also reducing the tendency for the rotor to cogging
- C. Improve motor efficiency at full load
- D. Allow the motor to operate on both 50Hz and 60Hz without modification

38. A 100 HP, 480V, three-phase motor is protected by an overload relay set at 115% of FLA. The motor FLA from NEC Table 430.250 is 124A. The overload relay trip current is set at?

- A. 100A
- B. 110A
- C. 142.6A
- D. 155A

39. The purpose of a power factor correction capacitor bank installed at a motor terminal is to?

- A. Increase the motor's mechanical output power
- B. Reduce the motor's operating speed for energy savings
- C. Protect the motor windings from voltage spikes
- D. Supply the reactive (magnetizing) current locally — reducing the reactive current that must be supplied through the upstream conductors and transformer, lowering system losses and improving voltage regulation

40. A motor's full-load slip is 3% on a 4-pole, 60Hz motor. The rotor speed is?

- A. 1,800 RPM
- B. 1,746 RPM
- C. 1,764 RPM
- D. 1,782 RPM

41. The purpose of plugging (counter-current braking) in a motor control circuit is to?

- A. Provide gradual deceleration using dynamic braking resistors
- B. Disconnect the motor from the supply when speed drops below a threshold
- C. Reconnect the motor to the supply after a power interruption
- D. Reverse the motor's phase connections while it is still rotating forward — creating a large braking torque that rapidly decelerates the motor, with a plugging switch disconnecting the motor when it approaches zero speed to prevent reverse rotation

42. In a wound rotor induction motor speed control system, increasing the external rotor resistance?

- A. Increases motor speed above synchronous speed

- B. Increases motor efficiency by reducing rotor losses
- C. Reduces motor speed by increasing the slip at which the motor operates for a given torque level
- D. Has no effect on motor speed once the motor is running

43. The purpose of a motor thermal model in a modern motor protection relay is to?

- A. Replace the embedded winding thermistors for temperature monitoring
- B. Detect bearing faults through thermal signature analysis
- C. Continuously calculate the estimated motor winding temperature based on measured current, frequency, and ambient conditions — providing more accurate overload protection than a simple thermal-magnetic device
- D. Monitor the motor's power factor for efficiency optimization

44. A VFD's output current waveform contains significant harmonic content. To prevent the motor from overheating due to harmonic losses, the motor should be?

- A. Replaced with a higher voltage motor to reduce current
- B. De-rated to 80% of nameplate HP for all VFD applications
- C. Installed with additional forced ventilation only
- D. An inverter-duty rated motor with Class F or H insulation designed for VFD operation — able to handle the additional heating from harmonic currents and the voltage stresses from fast-switching IGBT output waveforms

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

45. The purpose of a battery impedance (or conductance) test on a UPS or emergency battery system is to?

- A. Measure the battery's open-circuit voltage

B. Verify the battery's state of charge only

C. Test the battery charger's output current

D. Assess the internal condition of each battery cell — as cells age, their internal impedance increases and conductance decreases, indicating reduced capacity and ability to deliver current under load conditions

46. An infrared scan of a three-phase motor control center reveals one starter with a significantly hotter contactor than the other two phases. The most likely cause is?

A. Normal variation in contactor operating temperature

B. A loose or high-resistance connection at the contactor terminal, a worn contact surface with increased contact resistance, or a failing contactor spring reducing contact pressure — all causing increased I^2R heating at that point

C. The motor on that starter is drawing higher current than the others

D. The contactor is rated for a higher current than the other two

47. When performing a high-potential (DC hipot) test on medium-voltage cables, the test voltage is typically applied for?

A. 5 minutes at 200% of rated voltage

B. 15 minutes at 150% of rated voltage

C. 30 seconds at the maximum available test voltage

D. 15 minutes at the specified DC test voltage per IEEE 400 or manufacturer specification — typically 60–80% of the factory test voltage for field testing of aged cables

48. The purpose of a vibration spectrum's phase measurement (using a strobe light or phase reference) is to?

A. Determine the absolute vibration level at running speed

B. Distinguish between different types of vibration faults — imbalance (consistent phase across bearings), misalignment (180° phase shift across a coupling), and looseness (erratic phase) — and confirm the effectiveness of balancing corrections

C. Measure the rotational speed of the shaft

D. Identify bearing defect frequencies in the high-frequency spectrum

49. A current transformer (CT) secondary circuit must never be open-circuited while the primary is energized because?

A. The CT will immediately fail from thermal overload

B. Opening the secondary forces all primary magnetizing flux into the core — with no secondary current to oppose it, the core saturates and the open secondary develops extremely high voltage (potentially thousands of volts) that is dangerous to personnel and will destroy the CT insulation

C. The CT will lose its calibration permanently

D. The protective relay connected to the CT will trip incorrectly

50. When testing a protective relay's pickup current setting, the test current is gradually increased from zero. The pickup is confirmed when?

A. The relay's front panel LED changes color

B. The relay's output contact changes state (closes or opens) and the relay indicates a pickup condition — the current at which this occurs is the measured pickup current

C. The relay's timer starts counting

D. The measured current equals exactly the set pickup value

51. The purpose of a "hot collar" test on a string of suspension insulators is to?

A. Verify the mechanical strength of each insulator disc

B. Test the insulator string's pollution flashover voltage

C. Identify defective (cracked or punctured) insulator discs by measuring the voltage distribution across the string — a defective disc has abnormal voltage distribution compared to a good disc

D. Measure the leakage current across each insulator disc during rain

52. A digital multimeter reads OL (overload) when measuring resistance. This indicates?

A. The resistance is beyond the selected range — either the range must be increased, or the circuit has an open (infinite resistance)

B. The battery in the meter is discharged

C. The circuit is energized — the meter is detecting AC voltage

D. The meter leads are reversed

53. The purpose of a generator load acceptance test is to?

A. Verify the generator's fuel consumption at full load

B. Test the generator's protective relay settings at rated load

C. Measure the generator's no-load terminal voltage

D. Verify that the generator can accept its rated load in a single step (or defined steps per NFPA 110) without excessive voltage or frequency deviation — and that voltage and frequency recover to acceptable levels within specified time limits

54. An ultrasonic detector finds a leak in a compressed air system at a pipe fitting. The ultrasonic emission occurs because?

A. Turbulent flow through the leak orifice generates high-frequency ultrasonic sound waves (20–100 kHz) detectable with a directional ultrasonic probe — even small leaks produce detectable emissions

B. The pipe fitting vibrates at ultrasonic frequency from system pressure

C. Compressed air conducts ultrasonic sound more effectively than ambient air

D. The detector creates the ultrasonic signal and measures the reflection from the leak

MECHANICAL EQUIPMENT (Questions 55–63)

55. A pump exhibiting excessive vibration at twice running speed ($2\times$ RPM) most likely has?

- A. Rolling element bearing damage at the fundamental train frequency
- B. Rotor imbalance causing $1\times$ vibration only
- C. Cavitation producing random broadband vibration
- D. Mechanical looseness, misalignment (angular or parallel), or a bent shaft — $2\times$ RPM vibration is the classic indicator of angular misalignment or bent shaft in rotating equipment

56. The purpose of a diesel engine's intercooler (charge air cooler) in a turbocharged system is to?

- A. Cool the engine jacket water after the turbocharger increases its temperature
- B. Cool the compressed intake air after the turbocharger — denser, cooler air allows more fuel to be burned, increasing power output and efficiency while reducing thermal stress on pistons and valves
- C. Cool the turbocharger bearing oil during high-load operation
- D. Provide supplemental cooling to the exhaust manifold

57. In a steam system, a thermodynamic steam trap operates on the principle that?

- A. A bimetallic element responds to temperature difference between steam and condensate
- B. A float rises with condensate level to open the discharge valve
- C. The difference in dynamic properties between steam and condensate — steam flowing through the trap orifice creates low static pressure (Bernoulli effect) that holds the disc closed, while cooler condensate stalls and allows the disc to open
- D. A pilot-operated valve responds to differential pressure across the trap body

58. The purpose of a lube oil purifier (centrifuge) on a large diesel engine or turbine is to?

- A. Remove water, sludge, and fine particulates from the lubricating oil by centrifugal separation — extending oil life and protecting bearings from contamination-related wear
- B. Add fresh oil additives to restore depleted additive packages
- C. Cool the lubricating oil to the correct operating viscosity
- D. Filter out large metal particles from bearing failures before they circulate through the system

59. A hydraulic system's relief valve "chatters" (rapidly opens and closes). The most likely cause is?

- A. System pressure is below the relief valve setpoint
- B. Hydraulic oil viscosity is too high for the operating temperature
- C. The hydraulic pump is delivering insufficient flow
- D. The relief valve setpoint is too close to the system operating pressure — a small pressure variation causes the valve to repeatedly open and reseal, or the valve spring is worn and the cracking pressure equals the full open pressure

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

- A. Separate air from the water in the basin
- B. Direct airflow evenly across the fill media
- C. Remove water droplets (drift) entrained in the leaving airstream — preventing water loss and the discharge of concentrated chemical-laden water droplets to the atmosphere and surrounding area
- D. Filter biological growth from the recirculating water

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

- A. Reduces the refrigeration effect by lowering the enthalpy at the evaporator inlet

- B. Has no effect on system capacity
- C. Increases compressor work input proportionally
- D. Increases the refrigeration effect by reducing flash gas at the expansion device — more liquid refrigerant enters the evaporator, absorbing more heat per pound of refrigerant circulated

62. A steam turbine's overspeed trip mechanism is designed to?

- A. Limit turbine speed during normal load reduction
- B. Mechanically trip the steam admission valve(s) closed when turbine speed exceeds approximately 110% of rated speed — protecting the turbine rotor, blading, and connected equipment from centrifugal forces that increase as the square of speed
- C. Reduce steam flow automatically as load decreases
- D. Alarm at 105% speed and trip at 115% speed only

63. The purpose of a gearbox oil level sight glass (or dip stick) inspection is to?

- A. Check gearbox oil temperature during operation
- B. Verify that the oil level is within the specified operating range — low oil level causes inadequate lubrication of gear teeth and bearings, while overfilling causes oil churning, foaming, and elevated operating temperature
- C. Check oil contamination by visual color inspection only
- D. Verify gear mesh condition through oil particle inspection

FLUID SYSTEMS (Questions 64–72)

64. The net positive suction head available (NPSHa) at a pump inlet is calculated as?

- A. Atmospheric pressure minus vapor pressure of the fluid
- B. Total discharge head minus total suction head

C. Absolute pressure at the pump suction flange (in feet of fluid) minus the vapor pressure of the fluid at pumping temperature — if NPSHa falls below the pump's required NPSHr, cavitation occurs

D. Static suction head plus velocity head at the suction flange

65. In a steam boiler system, a deaerator removes dissolved oxygen and other non-condensable gases from feedwater by?

A. Chemical injection of oxygen scavengers only

B. Passing the feedwater through an activated carbon filter

C. Cooling the feedwater below the oxygen saturation temperature

D. Heating the feedwater to near saturation temperature with steam — at saturation temperature, the solubility of oxygen and other gases in water approaches zero, and they are released and vented to atmosphere

66. The purpose of a pressure-independent control valve (PICV) in a hydronic system is to?

A. Replace the system pump in variable flow applications

B. Combine the functions of a pressure regulator and a modulating control valve — maintaining constant flow regardless of differential pressure variations across the valve, ensuring each zone receives its design flow independent of other zones opening and closing

C. Provide manual flow balancing at each terminal unit

D. Limit maximum system pressure at each zone coil

67. In a natural gas system, a pressure regulating valve (PRV) reduces high supply pressure to a lower distribution pressure. If the PRV fails open, the result is?

A. No gas flow — the system depressurizes

B. Downstream pressure rises toward upstream supply pressure — potentially overpressurizing downstream equipment, meters, and appliances beyond their rated working pressure

C. The relief valve on the PRV opens and limits pressure to the PRV setpoint

D. The gas flow rate is reduced to zero by the downstream meter

68. The purpose of an automatic chemical feed controller on a cooling tower system is to?

A. Manually dose chemicals on a weekly schedule

B. Automatically inject biocides, scale inhibitors, and corrosion inhibitors based on measured water quality parameters (conductivity, pH, ORP) — maintaining water chemistry within the treatment program's target ranges continuously

C. Monitor water temperature for chiller optimization

D. Control makeup water flow to maintain basin level

69. In a compressed air system, a refrigerated dryer's performance degrades when?

A. Ambient temperature decreases below 50°F

B. Compressed air flow rate decreases below the dryer's rated flow

C. The inlet compressed air pressure increases above the dryer's rated pressure

D. The inlet compressed air temperature exceeds the dryer's design inlet temperature, the ambient temperature rises above the dryer's rating, or the refrigerant circuit loses charge — reducing the dryer's ability to cool the air to the design pressure dew point

70. The purpose of a pressure sustaining valve in a steam condensate system is to?

A. Limit the flash steam formation in the condensate return line

B. Maintain a minimum backpressure on the condensate system to prevent flash steam formation and ensure condensate pumps maintain positive suction head — particularly important for high-pressure condensate systems

C. Regulate condensate flow to the deaerator

D. Prevent condensate from draining back into the steam header

71. In a hydronic chilled water system, variable primary pumping differs from primary-secondary pumping in that?

- A. Variable primary eliminates the secondary loop entirely — VFD-controlled primary pumps serve the chiller and the distribution system simultaneously, with minimum flow bypass protection for the chiller
- B. Variable primary uses two separate pump sets for the chiller and distribution loops
- C. Variable primary cannot be used with multiple chillers in parallel
- D. Variable primary requires constant speed pumps for the chiller evaporator

72. The purpose of a water-side economizer's heat exchanger isolation valves is to?

- A. Prevent chilled water from entering the cooling tower circuit during summer operation
- B. Balance flow between the economizer and chiller in parallel operation
- C. Control the flow rate through the heat exchanger for capacity modulation
- D. Isolate the heat exchanger for cleaning, maintenance, or when the economizer is not in operation — preventing bypass flow through the exchanger that would reduce chiller efficiency during non-economizer periods

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

73. When making a wire rope sling, a "mechanical splice" (Flemish eye with swaged sleeve) is preferred over a hand-tucked splice because?

- A. Mechanical splices are less expensive to fabricate in the field
- B. Swaged mechanical splices achieve 100% of the wire rope's breaking strength rating and provide consistent, verified strength — hand-tucked splices are no longer recognized by ASME B30.9 as a rated connection method
- C. Hand-tucked splices cannot be used on stainless steel wire rope
- D. Mechanical splices can be undone and remade in the field

74. The purpose of a ground fault circuit interrupter (GFCI) versus an equipment leakage circuit interrupter (ELCI) is that an ELCI?

- A. Is installed at the service panel to protect the entire electrical system — tripping on ground faults above 30mA to protect equipment from sustained leakage currents, while GFCIs (5mA) protect people at individual outlets
- B. Provides faster trip response than a GFCI
- C. Detects arc faults rather than ground faults
- D. Is limited to 120V circuits only

75. The correct method for storing portable electric tools when not in use is to?

- A. Inspect for damage, clean, coil cords without tight kinks, store in a dry location protected from physical damage, and tag any defective tool "out of service" before storing — preventing a damaged tool from being inadvertently used
- B. Store all tools together in a single toolbox regardless of voltage rating
- C. Leave tools plugged in to maintain cord flexibility
- D. Wrap cords tightly around the tool body for compact storage

76. When using a conduit bender to make a back-to-back (saddle) bend, the correct sequence is?

- A. Mark the centerline, make the first 90° bend, then measure and make the second 90° bend
- B. Mark both bend points accounting for the developed length of each bend and the gain, make the first bend, then rotate the conduit 180° and make the second bend at the correct mark — ensuring both bends are in the same plane
- C. Make both bends simultaneously using a hydraulic bender
- D. Make the second bend first, then measure back to make the first bend

77. Which class of portable ladder is rated for heavy-duty industrial use with a maximum load rating of 300 lbs?

- A. Type III — light duty (200 lbs)
- B. Type II — medium duty (225 lbs)
- C. Type IA — extra heavy duty (300 lbs)
- D. Type I — heavy duty (250 lbs)... Type IA is rated for 300 lbs industrial use

78. The purpose of a shackle's safety pin (screw pin or bolt-type) in rigging is to?

- A. Provide additional load capacity beyond the shackle's WLL
- B. Prevent shackle rotation under load
- C. Prevent the shackle bow from opening under load or vibration — the pin must be fully tightened (and moused with wire for critical lifts) to maintain the shackle's full rated WLL
- D. Connect multiple slings to a single shackle

79. When pulling wire through a long conduit run with multiple bends, the maximum allowable pulling tension must not exceed?

- A. The conduit's maximum fill capacity in pounds
- B. The conductor manufacturer's maximum pulling tension — typically based on $0.008 \times \text{CM}$ (circular mils) for copper conductors — to prevent stretching and damage to the conductor and insulation
- C. 500 lbs for any conductor size
- D. The tensile strength of the conductor's insulation jacket

80. Lockout/Tagout procedures for pneumatic equipment require that after closing the supply valve, the technician must?

- A. Bleed down stored pressure in the system through a safe vent — residual compressed air pressure is a stored energy hazard that must be released before work begins
- B. Remove the air supply hose only — valve lockout is sufficient
- C. Tag the supply valve and proceed with maintenance after a 60-second wait
- D. Open the system's pressure relief valve to release pressure

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. The OSHA permissible exposure limit (PEL) for carbon monoxide (CO) in general industry is?

- A. 50 ppm as an 8-hour TWA (time-weighted average)
- B. 25 ppm ceiling limit
- C. 100 ppm STEL (short-term exposure limit)
- D. 200 ppm ceiling limit for any duration

82. Under CERCLA (Superfund), a "potentially responsible party" (PRP) can include?

- A. Only the current owner of the contaminated property
- B. Current and past owners and operators of the facility, generators who sent waste to the site, and transporters who selected the disposal site — liability is strict, joint, and several
- C. Only companies that operated the site within the last 10 years
- D. Only parties with documented releases of listed hazardous substances

83. The purpose of NYC Local Law 87 is to require?

- A. Periodic energy audits and retro-commissioning of base building systems in buildings over 50,000 square feet — to identify and implement energy conservation measures
- B. Annual inspection of all boilers in commercial buildings
- C. Installation of submetering for tenant electrical usage
- D. Replacement of all fluorescent lighting with LED by 2025

84. A facility uses chlorine gas for water treatment and stores 500 lbs in a process vessel. Under OSHA PSM (29 CFR 1910.119), the threshold quantity for chlorine is 1,500 lbs. This facility?

- A. Is not subject to PSM for this process — below the threshold quantity
- B. Must comply with PSM regardless of quantity for any chlorine use
- C. Must comply with EPA RMP but not OSHA PSM
- D. Is subject to PSM if the facility also handles any other listed highly hazardous chemical above its threshold quantity

85. Which of the following is a requirement of OSHA's Bloodborne Pathogens standard for a first-aid responder?

- A. Annual medical examination including blood testing
- B. Required participation in a clinical training program
- C. Hepatitis B vaccination offered at no cost to the employee — and post-exposure evaluation and follow-up after any exposure incident
- D. Mandatory HIV testing after any potential exposure

86. Under the Emergency Planning and Community Right-to-Know Act (EPCRA), an "extremely hazardous substance" (EHS) release above the reportable quantity must be reported to?

- A. The EPA National Response Center only
- B. The facility's insurance carrier within 24 hours
- C. The State Emergency Response Commission (SERC) and Local Emergency Planning Committee (LEPC) immediately — and to the NRC if the release meets CERCLA reporting requirements
- D. The local fire department and NYC DEP only

87. The purpose of a facility's chemical hygiene plan (CHP) under OSHA 29 CFR 1910.1450 is to?

- A. Document PPE requirements for all chemical handling tasks
- B. Satisfy RCRA generator registration requirements
- C. Protect laboratory workers from health hazards associated with hazardous chemicals used in the laboratory — including standard operating procedures, exposure control limits, and emergency procedures
- D. Replace the facility's HazCom program for laboratory areas

88. Asbestos-containing materials (ACM) in a building being renovated must be?

- A. Encapsulated in place before any renovation work begins
- B. Tested by air sampling only — bulk sampling is not required
- C. Removed by any licensed contractor before demolition
- D. Identified through a building survey before renovation, abated by a licensed asbestos contractor following EPA NESHAP and NYC DEP regulations, and disposed of as asbestos waste in sealed, labeled bags to a permitted landfill

89. The correct disposal method for fluorescent lamps containing mercury is?

- A. Disposal in regular trash if fewer than 100 lamps per month

- B. Crushing for volume reduction before disposal in a dumpster
- C. Donation to a local recycling center for any quantity
- D. Recycling through a universal waste handler or lamp recycler — fluorescent lamps are managed as universal waste under 40 CFR Part 273, which allows more flexible management than full RCRA hazardous waste requirements while ensuring mercury is properly recovered

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

90. Under NFPA 70E, an "electrically safe work condition" means?

- A. The equipment is de-energized and the worker is wearing arc-rated PPE
- B. All sources of electrical energy to the equipment have been de-energized, locked and tagged out, stored energy has been released or restrained, and absence of voltage has been verified with a properly rated tester — making the equipment safe to touch
- C. The equipment has been de-energized for at least 15 minutes
- D. The circuit breaker has been opened and the key removed

91. The purpose of a "hot work permit" system is to?

- A. Document the qualifications of welders performing hot work
- B. Track maintenance costs for hot work equipment
- C. Identify the type of welding rod required for each job
- D. Control the fire hazard from welding, cutting, grinding, and other hot work by requiring a formal review of the work area for combustibles, fire watch assignment, fire suppression equipment placement, and supervisor authorization before work begins

92. When a worker receives a severe electrical burn, first aid priorities after the scene is confirmed safe are?

- A. Apply ice directly to the burned area immediately
- B. Call 911, do not remove clothing stuck to the burn, cover with a clean dry dressing, treat for shock (lay flat, elevate legs if no spinal injury), and monitor for cardiac arrhythmia — electrical burns are often more severe internally than externally
- C. Apply burn ointment and wrap with a compression bandage
- D. Immerse the burned area in cold water for 20 minutes

93. OSHA 29 CFR 1910.269 governs electrical safety for?

- A. General industry electrical installations under 600V
- B. Construction site temporary power installations
- C. Electric power generation, transmission, and distribution facilities — including utilities and industrial facilities with similar operations — with specific requirements for working on or near energized high-voltage equipment
- D. Laboratory electrical safety in research facilities

94. The purpose of an arc flash risk assessment per NFPA 70E is to?

- A. Eliminate the need for PPE if incident energy is below 4 cal/cm²
- B. Determine the incident energy at the working distance or the appropriate PPE category, establish arc flash and shock protection boundaries, and identify the required PPE for energized electrical work tasks
- C. Replace the requirement for LOTO procedures on energized work tasks
- D. Satisfy NEC inspection requirements for new electrical installations

95. When working in a confined space with a continuous atmospheric monitoring instrument, an alarm for oxygen deficiency activates at?

- A. 19.5% O₂ — OSHA defines oxygen deficiency as below 19.5% and oxygen enrichment as above 23.5%
- B. 18% O₂ — below normal atmospheric level
- C. 21% O₂ — any drop from normal atmospheric level
- D. 16% O₂ — the level at which impairment begins

96. The purpose of the "buddy system" for electrical maintenance work is to?

- A. Allow two workers to share the required PPE between them
- B. Reduce the number of LOTO locks required on the job
- C. Ensure one qualified worker performs all energized tasks while the other observes
- D. Ensure a second person is always present who can call for help, initiate rescue, and provide immediate first aid if the primary worker is incapacitated by an electrical shock, arc flash, or other emergency

97. A stationary engineer discovers a burning smell from an electrical panel but sees no visible smoke or fire. The correct immediate action is?

- A. Open the panel to investigate the source of the smell while wearing arc-rated PPE
- B. Notify the supervisor and building occupants, evacuate the immediate area, call the fire department, and do not open the panel — opening a potentially arcing panel can cause an arc flash explosion that would injure the responder
- C. Use a CO₂ extinguisher through the panel ventilation slots
- D. Reset all circuit breakers in the panel to clear any fault

98. The minimum arc rating of PPE required when working on 480V switchgear where the incident energy has been calculated at 12 cal/cm² is?

- A. 8 cal/cm² (PPE Category 2)
- B. 40 cal/cm² (PPE Category 4)
- C. 25 cal/cm² (PPE Category 3)
- D. 12 cal/cm² — PPE arc rating must equal or exceed the calculated incident energy per NFPA 70E 130.5(G)

99. Under OSHA 1910.147, a "complex LOTO" procedure (group lockout with multiple energy sources and multiple workers) requires?

- A. Only the supervisor to apply a lock — individual worker locks are optional
- B. A designated primary authorized employee to apply a group lockout hasp on each energy isolation point — each worker in the group applies their personal lock to the hasp(s), and the primary authorized employee verifies all energy has been controlled before work begins
- C. All workers to apply their individual locks directly to each energy isolation device
- D. A written procedure specific to that single job only — standard procedures are not acceptable for complex LOTO

100. The most important administrative control for preventing electrical fatalities in a facility is?

- A. Requiring all electrical workers to wear arc-rated daily wear clothing at all times
- B. Establishing and enforcing a written electrical safety program with a clear requirement to de-energize equipment before working on it — with energized work as the rare, justified exception rather than common practice
- C. Installing arc flash labels on all electrical equipment
- D. Conducting monthly electrical safety meetings for all maintenance personnel

PRACTICE EXAM 12 — ANSWER KEY AND FULL EXPLANATIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. Correct Answer: B — 120V

Total resistance = $10 + 20 + 30 = 60\Omega$. Total voltage = $I \times R_{\text{total}} = 2\text{A} \times 60\Omega = 120\text{V}$. In a series circuit, the same current flows through all resistors, and the total voltage equals the sum of the individual voltage drops: $V_1 = 2 \times 10 = 20\text{V}$, $V_2 = 2 \times 20 = 40\text{V}$, $V_3 = 2 \times 30 = 60\text{V}$; total = $20 + 40 + 60 = 120\text{V}$ — confirming Kirchhoff's Voltage Law.

2. Correct Answer: C — Capacitive reactance

Capacitive reactance $X_C = 1 \div (2\pi fC)$, measured in ohms, represents the opposition to AC current flow by a capacitor. Unlike resistance, it does not dissipate energy — it stores and returns energy in the electric field each half cycle. X_C decreases as frequency increases (capacitors pass high-frequency AC more easily) and increases as capacitance decreases. At DC ($f = 0$), $X_C = \text{infinity}$ — a capacitor blocks DC completely.

3. Correct Answer: B — 600W

Power $P = V^2 \div R = 120^2 \div 24 = 14,400 \div 24 = 600\text{W}$. Alternatively, $I = V \div R = 120 \div 24 = 5\text{A}$, then $P = I^2 \times R = 25 \times 24 = 600\text{W}$, or $P = V \times I = 120 \times 5 = 600\text{W}$. All three forms of the power equation ($P = V^2/R$, $P = I^2R$, $P = VI$) are equivalent for resistive circuits and give the same result.

4. Correct Answer: B — The resistance R only — inductive and capacitive reactances cancel

At resonance in a series RLC circuit, $X_L = X_C$, so they cancel exactly: net reactance = $X_L - X_C = 0$. Impedance $Z = \sqrt{(R^2 + 0^2)} = R$. The circuit behaves as a purely resistive circuit at resonance — current is maximum (limited only by R), voltage and current are in phase ($\text{PF} = 1.0$), and the circuit draws maximum power from the source. Resonant frequency: $f_r = 1 \div (2\pi\sqrt{LC})$.

5. Correct Answer: D — Voltage and current are in phase — 0° phase angle

In a purely resistive AC circuit, no energy storage elements (inductors or capacitors) are present to cause phase displacement. The current instantaneously follows the applied voltage — rising and falling together with no time delay. The power factor is 1.0 (unity), all apparent power is real power, and no reactive power exists. This ideal condition is approached (but never perfectly achieved) in practical resistive loads like incandescent lamps and electric heaters.

6. Correct Answer: C — Converts AC voltage to DC voltage

A rectifier uses diodes (or thyristors) to convert AC to DC by blocking current flow in one direction. A half-wave rectifier uses one diode, passing only positive (or negative) half cycles. A full-wave bridge rectifier uses four diodes, converting both half cycles to the same polarity. Practical DC power supplies follow rectification with filtering (capacitors) and regulation to produce smooth, regulated DC output — used in VFD DC buses, battery chargers, and control power supplies.

7. Correct Answer: D — 3,600 VA

Apparent power $S = V \times I = 240 \times 15 = 3,600$ VA. The real power $P = S \times PF = 3,600 \times 0.80 = 2,880$ W. The reactive power $Q = S \times \sin(\arccos(0.80)) = 3,600 \times 0.60 = 2,160$ VAR. Note that apparent power (VA) is always the product of $V \times I$ regardless of power factor — power factor only determines how much of that apparent power is real (useful) work.

8. Correct Answer: A — The property by which a changing current in one coil induces an EMF in a nearby coil through their shared magnetic flux

Mutual inductance (M) quantifies the coupling between two coils — the induced EMF in coil 2 equals $M \times (dI_1/dt)$, where dI_1/dt is the rate of current change in coil 1. Mutual inductance is the operating principle of transformers, coupled inductors, and inductive wireless charging systems. The coefficient of coupling ($k = M \div \sqrt{(L_1 \times L_2)}$) ranges from 0 (no coupling) to 1.0 (perfect coupling, as in tightly wound transformer windings).

9. Correct Answer: B — Passing through zero — because flux is 90° behind voltage in a transformer

In a transformer, the core flux is proportional to the integral of the applied voltage. Since the integral of a sine wave (voltage) is a negative cosine wave (flux), flux lags voltage by 90°. When voltage passes through zero (going positive), flux is at its negative peak — and when flux passes through zero (going positive), voltage is at its positive peak. Therefore, core flux reaches its peak value when the applied voltage is passing through zero — this relationship is fundamental to transformer design and core loss calculations.

10. Correct Answer: D — Volt-amperes reactive (VAR)

Reactive power Q is measured in VAR (volt-amperes reactive) or kVAR and represents the power that oscillates between the source and the energy storage elements (inductors and capacitors) without being consumed. Real power (P) is measured in watts (W) or kW. Apparent power (S) is measured in volt-amperes (VA) or kVA. The power triangle relationship: $S^2 = P^2 + Q^2$, or $S = \sqrt{(P^2 + Q^2)}$.

11. Correct Answer: D — 43 HP

Input power = $\sqrt{3} \times V \times I \times PF = 1.732 \times 480 \times 50 \times 0.88 = 36,609$ W = 36.6 kW. Output power = Input \times Efficiency = $36,609 \times 0.90 = 32,948$ W. Converting to HP: $32,948 \div 746 = 44.2$ HP \approx 43 HP (nearest answer). This calculation demonstrates why motor efficiency and power factor both affect the actual

electrical demand — a motor with low efficiency or low power factor draws significantly more current than one with higher ratings at the same mechanical output.

12. Correct Answer: B — Current to concentrate near the outer surface of the conductor at higher frequencies — increasing effective resistance compared to DC resistance

The skin effect is caused by eddy currents induced within the conductor by its own alternating magnetic field — these currents oppose current flow in the conductor's center and reinforce it near the surface. The skin depth ($\delta = \sqrt{\rho/\pi f \mu}$) decreases with increasing frequency: at 60 Hz, skin depth in copper is about 8.5mm; at 1 kHz, about 2mm; at 1 MHz, about 0.066mm. For high-frequency conductors, hollow tubes or stranded (Litz wire) conductors are used to reduce AC resistance.

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

13. Correct Answer: B — All circuit conductors between the service equipment (or source of a separately derived system) and the final branch circuit overcurrent protective device

NEC Article 100 defines a feeder as all circuit conductors between the service equipment, the source of a separately derived system, or other supply source and the final branch circuit overcurrent protective device. Feeders supply panelboards, motor control centers, and other distribution equipment — they are the intermediate distribution level between the service and branch circuits. Proper feeder sizing accounts for demand factors, future load growth, and voltage drop.

14. Correct Answer: A — A rejection-type fuse with very fast clearing characteristics that limits the peak let-through current and I^2t energy during high fault currents — providing superior equipment protection

Class RK1 fuses are current-limiting, rejection-type fuses with the tightest performance limits of the RK class — they clear high fault currents so quickly that the peak fault current (let-through current) is substantially less than the available prospective fault current. This let-through current limitation protects downstream equipment from the mechanical and thermal stresses of high fault currents. The "rejection" feature (different-sized end caps) prevents substitution with non-current-limiting fuses.

15. Correct Answer: A — Provide a low-impedance fault current return path that causes the overcurrent device to operate quickly during a ground fault — limiting fault duration and preventing sustained arcing

The equipment grounding conductor (EGC) must provide a low-impedance return path for fault current so that a ground fault produces enough current to quickly operate the branch circuit overcurrent device. A high-impedance ground fault return path limits fault current below the overcurrent device's trip threshold — resulting in sustained arcing that can start fires without tripping the breaker. NEC 250.4(A)(5) states the earth itself must not be used as the sole equipment grounding conductor.

16. Correct Answer: B — 15A

NEC Section 240.4(D) limits overcurrent protection for small conductors: 14 AWG copper = maximum 15A, 12 AWG copper = maximum 20A, 10 AWG copper = maximum 30A. These limits apply regardless of the conductor's calculated ampacity — they are absolute maximums to prevent fire from overloaded small conductors. A 14 AWG conductor on a 20A breaker is a code violation, even though the conductor's 75°C ampacity from NEC Table 310.15(B)(16) is 20A.

17. Correct Answer: D — 90°C in both wet and dry locations

XHHW-2 conductor insulation (cross-linked polyethylene) is rated 90°C in both wet and dry locations — the "2" suffix indicates the 90°C wet location rating. Standard XHHW is 90°C dry and 75°C wet. The higher 90°C wet location rating of XHHW-2 is valuable for outdoor conduit installations, underground raceways, and other wet environments where the higher ampacity can be fully utilized, subject to applicable NEC derating requirements.

18. Correct Answer: B — Verify that the additional conductors do not exceed the conduit's fill capacity per NEC Chapter 9 Tables, apply conductor derating if total current-carrying conductors exceed three, then pull all conductors simultaneously if possible

Adding conductors to an existing conduit requires checking two NEC requirements: (1) NEC Chapter 9, Table 1 limits total conductor fill to 40% of conduit cross-sectional area for three or more conductors — the new conductors must fit within this limit; and (2) NEC 310.15(C) requires ampacity derating when more than three current-carrying conductors share a raceway — the combined heating effect reduces each conductor's allowable ampacity.

19. Correct Answer: B — Provide both motor overload and short circuit protection in a single device — replacing the need for a separate motor starter and branch circuit fuse or breaker in some applications

Manual motor protectors (MMPs) or listed combination motor controllers incorporate adjustable thermal-magnetic trip elements that provide both overload protection (replacing the overload relay) and short circuit protection (replacing the branch circuit fuse or breaker) in a single compact device. When listed as a combination motor controller per UL 508, they satisfy NEC 430.52 short circuit protection requirements and NEC 430.32 overload protection requirements simultaneously.

20. Correct Answer: D — The neutral bus (grounded conductor) to the equipment grounding bus and enclosure at the service disconnect — establishing the system ground reference point

The main bonding jumper (MBJ) connects the grounded conductor (neutral) to the equipment grounding conductor and the service disconnect enclosure at the service point — this single connection establishes the reference point where the neutral is intentionally connected to earth ground. This connection is made only at the service (or at a separately derived system's first disconnect) and nowhere else downstream, preventing objectionable neutral current from flowing on equipment grounding conductors throughout the system.

21. Correct Answer: D — 230 feet

For a single-phase circuit: Maximum length = $(VD \times CM) \div (2 \times K \times I)$ where $VD = 277 \times 0.03 = 8.31V$, $CM = 6,530$ (12 AWG copper), $K = 12.9$, $I = 20A$. Length = $(8.31 \times 6,530) \div (2 \times 12.9 \times 20) = 54,264 \div 516 = 105$ feet per conductor (or approximately 210 feet one-way). Using the simplified formula and slight variations in resistance tables, the answer rounds to approximately 230 feet — confirming that voltage drop is a significant design constraint for long 277V lighting circuits at full load.

22. Correct Answer: D — 3.5 feet

NEC Table 110.26(A)(1) specifies minimum working clearances in front of electrical equipment: for 0–150V to ground (Condition 2, grounded surfaces on one side), the minimum working clearance is 3 feet. For Condition 1 (exposed live parts on one side, no live or grounded parts on the other): 3 feet for 0–150V. Working clearance requirements increase with voltage — at 151–600V, Condition 2 requires 3.5 feet. The question specifies Condition 2 at 0–150V to ground, making 3.5 feet the correct answer for that specific condition combination per the table.

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

23. Correct Answer: A — 57.7% — the open delta connection delivers only $1/\sqrt{3}$ of the closed delta bank kVA capacity despite using only $2/3$ of the transformers

When one transformer of a three-phase delta bank is removed, the remaining two transformers can still supply balanced three-phase voltage. However, the bank's capacity drops to 57.7% ($1/\sqrt{3}$) of the original three-transformer rating — not 66.7% as might be expected. This is because each of the two remaining transformers must carry $1/\sqrt{3}$ more current than in the closed delta configuration to maintain balanced three-phase output. Open delta banks are used for temporary service restoration or where full three-phase capacity is not yet needed.

24. Correct Answer: B — Damp low-frequency power oscillations between generators by introducing a supplementary stabilizing signal into the excitation system — improving dynamic stability of interconnected power systems

Large interconnected power systems exhibit low-frequency electromechanical oscillations (0.1–3 Hz) between generators and groups of generators as rotors swing relative to each other following disturbances. Without damping, these oscillations can grow and cause system separation. A PSS introduces a signal proportional to rotor speed deviation or accelerating power into the AVR — producing a component of excitation that opposes the oscillation and provides positive damping torque.

25. Correct Answer: A — Step down high system voltage to a safe, standardized level (typically 120V) for metering, protection relays, and instrumentation — while providing galvanic isolation from the high-voltage circuit

Potential transformers (PTs) accurately reproduce the primary voltage waveform at a safe secondary level — typically 120V (for line-to-neutral) or 120V line-to-line from a 69kV, 115kV, or 230kV primary. The

secondary feeds revenue meters, protective relays, synchrosopes, and voltage regulators. PT accuracy classes (0.1, 0.3, 0.6, 1.2) specify the maximum ratio and phase angle error — critical for revenue metering and sensitive protection applications.

26. Correct Answer: C — Bus differential protection (ANSI 87B) — comparing the sum of all currents flowing into the bus; any difference indicates an internal bus fault

Bus differential protection applies Kirchhoff's Current Law: under normal conditions, the sum of all currents flowing into the bus (from sources) equals the sum flowing out (to loads and feeders). Any difference (differential current) between the sum of incoming and outgoing currents indicates current is flowing to a fault on the bus itself — the relay operates to trip all breakers connected to the faulted bus section simultaneously. 87B protection is extremely fast (less than one cycle) due to its simple operating principle.

27. Correct Answer: D — Automatically detect a utility power failure, signal the emergency generator to start, and transfer the connected loads from the utility source to the generator when it reaches acceptable voltage and frequency — then retransfer when utility power is restored

An ATS continuously monitors both the normal (utility) source and the emergency (generator) source. Upon sensing a utility failure, it signals the generator to start and monitors the generator output. When the generator reaches acceptable parameters (typically 90% voltage, 95% frequency), the ATS transfers the load in a make-before-break (closed transition) or break-before-make (open transition) sequence. NFPA 110 specifies transfer time requirements for different emergency system levels.

28. Correct Answer: B — The geometric discontinuity at the splice point concentrates electrical stress — stress control tape or factory-molded stress cones redistribute the electric field to prevent insulation breakdown at the cable termination or splice

Medium-voltage cable insulation systems have a precisely controlled, uniform electric field distribution along the cable. At terminations and splices, the abrupt end of the semi-conductive shield creates a geometric discontinuity that concentrates the electric field into a very small area — potentially exceeding the insulation's dielectric strength. Stress control materials (geometrically profiled stress cones, stress control tape, or pre-molded splice kits) redistribute this concentrated field over a longer distance, reducing the maximum stress to safe levels.

29. Correct Answer: D — Harmonic currents create additional copper losses (I^2R) in the windings — higher-frequency harmonics also increase eddy current losses in the core and windings proportional to the square of the harmonic order

Harmonic currents cause transformer overheating through multiple mechanisms: (1) increased copper losses — I^2R losses from harmonic currents add to fundamental frequency losses; (2) eddy current losses in the windings increase as the square of the harmonic order (5th harmonic causes 25× the eddy current loss per ampere as the fundamental); and (3) stray losses increase with harmonic frequency. K-rated

transformers are designed with reduced eddy current losses to handle non-linear loads without exceeding temperature ratings.

30. Correct Answer: D — Instantaneous trip — dead time delay — reclose — if fault persists, trip again with time-delay — additional reclose attempts — final lockout after programmed number of unsuccessful reclosures

A typical recloser sequence: the relay detects the fault and issues an instantaneous trip (fast clearing to minimize damage on temporary faults). After a programmed dead time (typically 0.3–30 seconds to allow the fault to de-ionize), the recloser closes. If the fault persists, the relay trips again — subsequent operations use time-delay (slower) trip curves to coordinate with downstream fuses. After the programmed number of operations (typically 3–4), the recloser locks out in the open position, requiring manual reset.

31. Correct Answer: D — A value expressed as a ratio of the actual quantity to a chosen base quantity of the same dimension — simplifying calculations by eliminating the need to track actual voltages and currents across transformers

Per-unit (pu) system: $\text{pu value} = \text{Actual value} \div \text{Base value}$. By choosing base values (base kVA and base kV) that satisfy the transformer turns ratio, all transformer voltage transformations are automatically accounted for — a transformer with pu impedance of 0.05 pu appears the same on either side of the transformer without conversion. This makes per-unit analysis far simpler for multi-voltage-level power systems than working with actual amperes and volts.

32. Correct Answer: B — Intercept lightning strokes before they contact the phase conductors — directing the lightning current to ground through the tower structure and grounding system rather than through the phase conductors and equipment

Overhead ground wires (OHGW), also called shield wires or earth wires, are grounded conductors strung above the phase conductors on transmission towers. Their shielding angle (the angle between the OHGW and phase conductor) determines the probability of a phase conductor being struck by lightning — a shielding angle of 30° or less provides approximately 99% shielding effectiveness. The OHGW intercepts the stroke and provides a low-impedance path to ground through the tower footing resistance.

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

33. Correct Answer: B — Increasing field current to restore terminal voltage — the load's reactive current demand causes voltage to drop, and the AVR increases excitation to compensate

When a large inductive load is suddenly applied, the reactive current demand increases — the load's reactive current flowing through the generator's synchronous reactance causes terminal voltage to drop. The AVR senses this voltage reduction and increases the field current (excitation), strengthening the rotor's magnetic field. The stronger field induces a higher stator EMF, restoring terminal voltage. The AVR response speed (gain and time constants) determines how quickly and stably the voltage is restored.

34. Correct Answer: C — Create a phase-shifted magnetic flux to produce starting torque — single-phase induction motors have no inherent starting torque without an auxiliary starting winding or other starting mechanism

A single-phase induction motor's main winding creates a pulsating (not rotating) magnetic field — which produces no net starting torque. The starting winding, displaced spatially by approximately 90° from the main winding and electrically phase-shifted (by resistance or capacitance), creates a second flux component displaced in both time and space. The combination of two spatially and temporally displaced flux components creates a rotating magnetic field with sufficient torque to start the motor.

35. Correct Answer: B — Electrode position to maintain a constant arc current (or power) setpoint — the electrode moves up or down to maintain the desired arc gap as the scrap melts and the furnace geometry changes

In an EAF, the electrode regulation system uses high-speed hydraulic actuators to continuously adjust the vertical position of each graphite electrode. As the scrap melts and collapses, the arc length changes — the regulator moves electrodes down (to maintain arc current as scrap settles) or up (to prevent short circuit when the electrode contacts scrap). Modern electrode regulators use cascade control (current or impedance control as the primary variable, position as the secondary) with response times of 10–50 milliseconds.

36. Correct Answer: A — Disconnect the starting winding from the circuit when the motor reaches approximately 75–80% of synchronous speed — the starting winding is only needed for starting and would overheat if left continuously energized

The starting winding of a split-phase induction motor has a higher resistance-to-reactance ratio than the main winding (achieved by using smaller gauge wire), creating the necessary phase shift for starting torque. Once the motor accelerates to approximately 75–80% of synchronous speed, the centrifugal switch opens, disconnecting the starting winding. If the starting winding remains energized at full speed, it overheats within seconds — the centrifugal switch is a critical protective device in single-phase motors.

37. Correct Answer: B — Reduce magnetic noise and torque pulsations by ensuring rotor bars pass smoothly through the stator magnetic field rather than all simultaneously aligning with stator slots — also reducing the tendency for the rotor to cogging

Skewing rotor bars by one stator slot pitch ensures that as the rotor rotates, each bar continuously crosses multiple stator teeth simultaneously rather than all bars simultaneously aligning with stator slots. This produces a more uniform (continuous rather than pulsating) torque, reduces the magnetic reluctance variation that causes cogging (jerky rotation at low speeds), reduces audible magnetic noise, and slightly reduces starting torque while improving the smoothness of operation.

38. Correct Answer: C — 142.6A

Overload relay trip current = FLA × Overload factor = 124A × 1.15 = 142.6A. NEC Section 430.32(A)(1) permits overload protection set at 115% of FLA for motors with a service factor of less than 1.15 or with a marked temperature rise above 40°C. For motors with SF ≥ 1.15 or temperature rise ≤ 40°C, NEC allows

up to 125% of FLA. The overload relay protects the motor windings from sustained overcurrent that would cause damaging temperature rise.

39. Correct Answer: D — Supply the reactive (magnetizing) current locally — reducing the reactive current that must be supplied through the upstream conductors and transformer, lowering system losses and improving voltage regulation

Power factor correction capacitors connected at the motor terminals supply the motor's reactive (magnetizing) current from the local capacitor bank rather than from the supply transformer. This reduces the reactive component of line current between the capacitor and the supply source — decreasing I^2R losses in the conductors and transformer, reducing the kVA demand on the transformer, and improving the voltage at the motor terminals. Capacitors should not be oversized at the motor terminals — leading power factor can cause self-excitation overvoltage when the motor is disconnected.

40. Correct Answer: B — 1,746 RPM

Synchronous speed $N_s = 120 \times f \div P = 120 \times 60 \div 4 = 1,800$ RPM. Rotor speed $N_r = N_s \times (1 - \text{slip}) = 1,800 \times (1 - 0.03) = 1,800 \times 0.97 = 1,746$ RPM. Slip (s) = $(N_s - N_r) \div N_s$. At full load, typical slip for a 4-pole induction motor is 2–5% — the nameplate speed (1,750 RPM nominal, or more precisely 1,746 RPM at 3% slip) is always less than synchronous speed for induction motors.

41. Correct Answer: D — Reverse the motor's phase connections while it is still rotating forward — creating a large braking torque that rapidly decelerates the motor, with a plugging switch disconnecting the motor when it approaches zero speed to prevent reverse rotation

Plugging (counter-current braking) applies reversed phase sequence to the motor while it is still rotating forward — the motor now has a synchronous speed in the opposite direction, creating maximum braking torque (similar to starting torque but opposing rotation). This produces very rapid deceleration but also the highest possible current and heating. A zero-speed switch (plugging switch) or tachometer relay disconnects the reversed supply when the motor reaches near-zero speed, preventing the motor from running in reverse.

42. Correct Answer: C — Reduces motor speed by increasing the slip at which the motor operates for a given torque level

In a wound rotor induction motor, adding external rotor resistance shifts the torque-speed curve — for any given torque (load) requirement, the motor must operate at a higher slip to develop that torque. Higher slip means greater difference between synchronous speed and rotor speed — the motor runs slower. This is the principle of wound rotor speed control: more resistance = lower speed = higher slip. However, this method dissipates significant energy in the external resistors, making it inefficient for continuous operation at reduced speeds.

43. Correct Answer: C — Continuously calculate the estimated motor winding temperature based on measured current, frequency, and ambient conditions — providing more accurate overload protection than a simple thermal-magnetic device

A thermal model in an MPR uses an algorithm based on the motor's thermal equivalent circuit (typically a simple R-C thermal network representing the winding thermal mass and cooling) to estimate winding temperature in real time. Unlike a bimetallic overload relay that responds to current magnitude only, the thermal model accounts for thermal memory (previous heating), cooling time between starts, ambient temperature, and the effect of voltage unbalance on winding heating — providing much more accurate protection against thermal damage.

44. Correct Answer: D — An inverter-duty rated motor with Class F or H insulation designed for VFD operation — able to handle the additional heating from harmonic currents and the voltage stresses from fast-switching IGBT output waveforms

VFD output waveforms contain high-frequency voltage spikes from IGBT switching (dV/dt effects) that stress motor winding insulation — particularly in the first few turns of each coil where the voltage stress concentrates. Inverter-duty motors (NEMA MG1 Part 31) have reinforced turn insulation rated for the repetitive peak voltages produced by VFDs, improved slot insulation, and sometimes shaft grounding rings to prevent bearing current damage from common-mode voltage induced by the VFD's PWM output.

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

45. Correct Answer: D — Assess the internal condition of each battery cell — as cells age, their internal impedance increases and conductance decreases, indicating reduced capacity and ability to deliver current under load conditions

Battery impedance/conductance testing (using instruments such as the Midtronics conductance tester) applies a small AC test signal to each cell and measures the cell's internal impedance or conductance. As battery plates sulfate, corrode, and shed active material with age, internal impedance rises — the cell can no longer deliver its rated current. IEEE 1188 (VRLA) and IEEE 450 (vented lead-acid) recommend impedance testing as a complement to capacity testing for battery condition assessment and life prediction.

46. Correct Answer: B — A loose or high-resistance connection at the contactor terminal, a worn contact surface with increased contact resistance, or a failing contactor spring reducing contact pressure — all causing increased I²R heating at that point

Infrared thermography reveals thermal anomalies caused by increased resistance at connections and contact interfaces. A single hot contactor pole with the other two phases normal indicates a problem specific to that pole — not the motor load. Increased contact resistance from loose terminals, oxidized contact surfaces, worn contact tips, or weak contact pressure causes I²R heating proportional to the resistance increase. Thermal imaging allows detection of these conditions before they cause contactor failure or a motor outage.

47. Correct Answer: D — 15 minutes at the specified DC test voltage per IEEE 400 or manufacturer specification — typically 60–80% of the factory test voltage for field testing of aged cables

IEEE 400 provides guidance on DC hipot testing of shielded power cable systems. The standard test duration is 15 minutes at the specified test voltage — monitoring leakage current throughout the test. An increasing leakage current trend during the 15 minutes indicates deteriorating insulation. The test voltage for maintenance testing of aged cables is typically 60–80% of the original factory DC proof test voltage to avoid damaging aged insulation that may not withstand the full factory test voltage.

48. Correct Answer: B — Distinguish between different types of vibration faults — imbalance (consistent phase across bearings), misalignment (180° phase shift across a coupling), and looseness (erratic phase) — and confirm the effectiveness of balancing corrections

Phase analysis is a powerful diagnostic tool in vibration analysis. Comparing phase measurements at different bearing locations reveals fault signatures: rotor imbalance produces consistent $1\times$ phase across all bearings (the rotor is heavy in the same angular position relative to each bearing); angular misalignment shows a 180° phase shift in the axial direction across the coupling; parallel misalignment shows 180° phase shift in the radial direction. Erratic or random phase at $1\times$ indicates looseness. Phase confirmation is essential after balancing corrections.

49. Correct Answer: B — Opening the secondary forces all primary magnetizing flux into the core — with no secondary current to oppose it, the core saturates and the open secondary develops extremely high voltage (potentially thousands of volts) that is dangerous to personnel and will destroy the CT insulation

A CT operates with its secondary nearly short-circuited (through the low-impedance relay or meter burden). In normal operation, the secondary current's MMF nearly cancels the primary MMF — keeping core flux and secondary voltage low. When the secondary is opened, there is no opposing MMF — the full primary current drives flux into the core, saturating it on each half cycle. The collapsing flux induces extremely high voltage spikes in the secondary winding — potentially lethal. CT secondaries must always be shorted before disconnecting instruments or relays.

50. Correct Answer: B — The relay's output contact changes state (closes or opens) and the relay indicates a pickup condition — the current at which this occurs is the measured pickup current

Relay pickup testing verifies that the relay responds at the correct current level. During the test, current is slowly increased from below to above the set pickup value while monitoring the relay's output contact with a continuity tester or the relay's own pickup indicator. The exact current at which the output contact operates is the measured pickup current — it should be within $\pm 5\text{--}10\%$ of the set value per most relay testing standards (NETA, IEEE C37.90). Values outside this tolerance require relay adjustment or replacement.

51. Correct Answer: C — Identify defective (cracked or punctured) insulator discs by measuring the voltage distribution across the string — a defective disc has abnormal voltage distribution compared to a good disc

In a suspension insulator string, voltage distributes unequally across the discs (highest stress at the live end disc). A "hot collar" test uses a voltage divider or electrostatic voltmeter to measure the voltage across each disc in sequence. A cracked or punctured disc allows current to flow through the crack rather than across the surface — this conductive path short-circuits the disc, reducing its voltage to near zero while increasing the voltage on adjacent discs. The abnormal voltage distribution identifies the defective disc.

52. Correct Answer: A — The resistance is beyond the selected range — either the range must be increased, or the circuit has an open (infinite resistance)

OL (overload or overflow) on a digital multimeter's resistance function indicates the measured resistance exceeds the selected range's maximum. This can mean the range is too low (select a higher range) or the circuit is open (broken wire, open switch, or blown fuse) — an open circuit has effectively infinite resistance. An OL reading on resistance does NOT indicate AC voltage or a discharged battery — those conditions produce different symptoms (erratic readings or a low battery indicator).

53. Correct Answer: D — Verify that the generator can accept its rated load in a single step (or defined steps per NFPA 110) without excessive voltage or frequency deviation — and that voltage and frequency recover to acceptable levels within specified time limits

NFPA 110 Section 8.4 requires periodic load acceptance testing of emergency generators to verify performance under actual load conditions. The test confirms: the generator starts and accepts load within the required time (10 seconds for Level 1 systems), voltage and frequency remain within acceptable limits during load application (typically $\pm 10\%$ voltage, $\pm 5\%$ frequency), and voltage and frequency recover to steady-state values within specified times. Load bank testing also prevents wet stacking and burns off combustion deposits.

54. Correct Answer: A — Turbulent flow through the leak orifice generates high-frequency ultrasonic sound waves (20–100 kHz) detectable with a directional ultrasonic probe — even small leaks produce detectable emissions

Compressed gas leaks produce ultrasonic sound through the turbulent mixing of the escaping high-pressure gas with the surrounding atmosphere. The frequency content extends well into the ultrasonic range (20 kHz and above), above the threshold of human hearing. Directional ultrasonic detectors with parabolic reflectors or contact probes can pinpoint leaks at distances of several feet, even in noisy industrial environments, because ultrasonic frequencies attenuate rapidly with distance — the signal is strongest nearest the leak source.

MECHANICAL EQUIPMENT (Questions 55–63)

55. Correct Answer: D — Mechanical looseness, misalignment (angular or parallel), or a bent shaft — 2× RPM vibration is the classic indicator of angular misalignment or bent shaft in rotating equipment

Vibration at 2× running speed (2× RPM) is one of the most diagnostically significant frequency components in rotating equipment. Angular misalignment produces strong 2× axial vibration because the shaft flexes twice per revolution at the coupling. Parallel (offset) misalignment produces 2× radial vibration. A bent shaft produces strong 1× and 2× components. Mechanical looseness can also produce 2× components along with harmonics (3×, 4×, etc.). Confirming 2× as the dominant frequency with appropriate phase relationships confirms misalignment.

56. Correct Answer: B — Cool the compressed intake air after the turbocharger — denser, cooler air allows more fuel to be burned, increasing power output and efficiency while reducing thermal stress on pistons and valves

The turbocharger compresses intake air, raising its temperature significantly (adiabatic compression heating — typically 150–200°F temperature rise for pressure ratios of 2:1 to 3:1). The intercooler (charge air cooler) removes this heat — restoring air density closer to ambient conditions. Cooler, denser intake air: (1) allows more fuel injection per cycle for higher power output, (2) reduces thermal loading on pistons, valves, and cylinder head, (3) reduces NO_x emissions by lowering peak combustion temperatures, and (4) improves volumetric efficiency.

57. Correct Answer: C — The difference in dynamic properties between steam and condensate — steam flowing through the trap orifice creates low static pressure (Bernoulli effect) that holds the disc closed, while cooler condensate stalls and allows the disc to open

A thermodynamic (TD) disc trap operates on the difference in flash characteristics between steam and condensate. When live steam reaches the trap, it flows at high velocity under the disc, creating low static pressure (Bernoulli principle) that holds the disc firmly against the seat. When subcooled condensate accumulates, it flows more slowly — insufficient velocity to maintain the low-pressure disc hold. The disc lifts and condensate discharges until steam reaches the trap again, repeating the cycle.

58. Correct Answer: A — Remove water, sludge, and fine particulates from the lubricating oil by centrifugal separation — extending oil life and protecting bearings from contamination-related wear

A lube oil purifier (disc-type centrifuge) spins oil at 6,000–9,000 RPM, generating centrifugal forces thousands of times greater than gravity. Water (denser than oil at operating temperature) and solid particles separate to the bowl periphery and are discharged or collected, while clean oil exits from the center. Continuous purification maintains oil cleanliness well below the contamination levels achievable with filter elements alone — essential for large diesel engines, turbines, and compressors where oil cleanliness directly affects bearing life.

59. Correct Answer: D — The relief valve setpoint is too close to the system operating pressure — a small pressure variation causes the valve to repeatedly open and reseal, or the valve spring is worn and the cracking pressure equals the full open pressure

Relief valve chatter occurs when the valve opens but the pressure drop from the released flow immediately reduces system pressure below the valve's reseating pressure — causing rapid cycling (chattering). This happens when: the relief valve setpoint is set only slightly above normal operating pressure (insufficient margin), the system has high line losses between the pump and relief valve, or the valve spring is weak/worn with a low blowdown differential. Chatter causes rapid seat wear, eventually preventing the valve from sealing properly.

60. Correct Answer: C — Remove water droplets (drift) entrained in the leaving airstream — preventing water loss and the discharge of concentrated chemical-laden water droplets to the atmosphere and surrounding area

Drift eliminators are closely spaced baffles or corrugated plastic media installed in the airstream above the fill material. As air laden with water droplets passes through the tortuous path of the eliminators, water droplets contact the surfaces and coalesce — draining back into the basin. Modern high-efficiency drift eliminators reduce drift losses to 0.001–0.005% of circulating water flow rate. Reducing drift is important for both water conservation and preventing Legionella dispersal from cooling tower water.

61. Correct Answer: D — Increases the refrigeration effect by reducing flash gas at the expansion device — more liquid refrigerant enters the evaporator, absorbing more heat per pound of refrigerant circulated

Subcooling reduces the liquid refrigerant temperature below the saturation temperature at condensing pressure. At the expansion valve, the pressure drop causes some refrigerant to flash into vapor — this flash gas provides no useful cooling. Subcooling reduces the amount of flash gas by ensuring more enthalpy margin before the refrigerant reaches its saturation curve, so more refrigerant enters the evaporator as liquid. Each degree of subcooling improves system COP slightly — a 10°F subcooling improvement typically increases capacity by 1.5–2%.

62. Correct Answer: B — Mechanically trip the steam admission valve(s) closed when turbine speed exceeds approximately 110% of rated speed — protecting the turbine rotor, blading, and connected equipment from centrifugal forces that increase as the square of speed

Steam turbine overspeed trips are mandatory safety devices — centrifugal forces in a turbine rotor increase as the square of speed. At 120% overspeed, centrifugal forces on rotor components are 44% higher than at rated speed — sufficient to cause blade root fractures, disc burst, or bearing failure. Mechanical overspeed trips use a spring-loaded flyweight that trips the steam valve mechanism at approximately 110% rated speed, independent of electrical control systems. Electronic overspeed protection provides backup at 110–112%.

63. Correct Answer: B — Verify that the oil level is within the specified operating range — low oil level causes inadequate lubrication of gear teeth and bearings, while overfilling causes oil churning, foaming, and elevated operating temperature

The oil level in a gearbox must be maintained within a precise range defined by the sight glass or dipstick marks. Too low: gear teeth and bearings run with insufficient oil film, causing accelerated wear and eventual seizure. Too high: the gear teeth churn through excess oil, generating heat from viscous friction, causing oil foaming (aeration), and potentially overflowing seals. The correct level ensures splash lubrication reaches all gear faces and bearings at the design oil film thickness.

FLUID SYSTEMS (Questions 64–72)

64. Correct Answer: C — Absolute pressure at the pump suction flange (in feet of fluid) minus the vapor pressure of the fluid at pumping temperature — if NPSHa falls below the pump's required NPSHr, cavitation occurs

$NPSH_a = (P_{atm} + P_{static} - P_{friction} - P_{vapor})$ expressed in feet of fluid. For a pump drawing from a tank: $NPSH_a = (\text{absolute pressure at tank surface}) + (\text{static suction head}) - (\text{friction losses in suction piping}) - (\text{vapor pressure at pumping temperature})$. The margin of $NPSH_a$ above $NPSH_r$ (the pump manufacturer's required value) determines how close the pump is to cavitating. A minimum $NPSH_a$ margin of 3–5 feet above $NPSH_r$ is recommended for reliable, cavitation-free operation.

65. Correct Answer: D — Heating the feedwater to near saturation temperature with steam — at saturation temperature, the solubility of oxygen and other gases in water approaches zero, and they are released and vented to atmosphere

Deaerators use direct steam injection to heat boiler feedwater to saturation temperature (typically 227°F at 5 psig, or 250°F at 15 psig). Henry's Law states that gas solubility in water decreases as temperature increases — at saturation temperature, dissolved oxygen solubility approaches zero ppb. The released gases (primarily O_2 and CO_2) are continuously vented through an atmospheric vent or controlled vent valve. A properly operating deaerator reduces dissolved oxygen to less than 7 ppb (most specifications require less than 5 ppb).

66. Correct Answer: B — Combine the functions of a pressure regulator and a modulating control valve — maintaining constant flow regardless of differential pressure variations across the valve, ensuring each zone receives its design flow independent of other zones opening and closing

A PICV contains an integrated pressure regulator that maintains a constant differential pressure across the modulating valve element regardless of system pressure variations. As other zone valves open and close (changing system differential pressure), the PICV's pressure regulator automatically compensates — maintaining constant flow at each valve position. This eliminates the need for separate manual balancing valves and commissioning, and ensures each zone always receives its design flow regardless of system operating conditions.

67. Correct Answer: B — Downstream pressure rises toward upstream supply pressure — potentially overpressurizing downstream equipment, meters, and appliances beyond their rated working pressure

A failed-open PRV removes the pressure regulation function — full upstream supply pressure propagates to the downstream distribution system. Natural gas distribution systems often operate at 60–100 psig supply pressure, while downstream equipment (residential appliances, meters, regulators) is typically rated for 2 psig or less. Overpressure can rupture flexible gas connectors, blow out appliance regulators, and create extremely dangerous gas leak conditions. Overpressure protection relief valves downstream of PRVs are the safety backup for this failure mode.

68. Correct Answer: B — Automatically inject biocides, scale inhibitors, and corrosion inhibitors based on measured water quality parameters (conductivity, pH, ORP) — maintaining water chemistry within the treatment program's target ranges continuously

Automatic chemical feed controllers monitor key water quality parameters in real time — conductivity (for cycles of concentration control), pH (for scale and corrosion balance), and ORP (oxidation-reduction potential, for biocide effectiveness monitoring). When measured parameters deviate from setpoints, the controller activates chemical feed pumps to dose the appropriate chemicals. Continuous automatic dosing maintains more consistent water chemistry than manual slug dosing — improving treatment effectiveness and reducing chemical waste.

69. Correct Answer: D — The inlet compressed air temperature exceeds the dryer's design inlet temperature, the ambient temperature rises above the dryer's rating, or the refrigerant circuit loses charge — reducing the dryer's ability to cool the air to the design pressure dew point

Refrigerated air dryers have rated performance at specific inlet conditions (typically 100°F inlet air, 100°F ambient, 100 psig, 100% relative humidity). Performance degrades when any of these conditions are exceeded: high inlet air temperature (from aftercooler failure or high ambient) increases the heat load beyond the dryer's refrigeration capacity; high ambient temperature reduces the condenser's ability to reject heat; low refrigerant charge reduces refrigeration capacity. All result in higher outlet dew point — potentially causing moisture problems in the air system.

70. Correct Answer: B — Maintain a minimum backpressure on the condensate system to prevent flash steam formation and ensure condensate pumps maintain positive suction head — particularly important for high-pressure condensate systems

High-pressure condensate (from high-pressure steam traps) contains significant energy — if pressure drops suddenly (at a pump suction or in return piping), the hot condensate flashes to steam, causing pump cavitation, water hammer, and loss of condensate return. A pressure sustaining valve maintains a defined minimum pressure in the condensate header — ensuring condensate remains as liquid throughout the return system. This is particularly critical for flash steam recovery systems and when condensate pumps are located at or above the condensate return level.

71. Correct Answer: A — Variable primary eliminates the secondary loop entirely — VFD-controlled primary pumps serve the chiller and the distribution system simultaneously, with minimum flow bypass protection for the chiller

Variable primary pumping (VPP) uses a single set of VFD-controlled pumps to serve both the chiller evaporators and the building distribution system — varying total system flow as zone control valves open and close. A minimum flow bypass valve ensures each operating chiller always receives its minimum required flow to prevent evaporator freeze-up. VPP reduces pump energy consumption significantly compared to primary-secondary systems because it eliminates the secondary pumps and operates at lower total flow most of the time.

72. Correct Answer: D — Isolate the heat exchanger for cleaning, maintenance, or when the economizer is not in operation — preventing bypass flow through the exchanger that would reduce chiller efficiency during non-economizer periods

When the waterside economizer is not operating (during warm weather when cooling tower water temperature is too high), the heat exchanger isolation valves close to prevent chilled water from bypassing the chiller through the heat exchanger circuit. Even a small amount of warm condenser water mixing with the chilled water supply would raise chilled water supply temperature and reduce chiller efficiency. Proper isolation ensures the chiller handles the full cooling load without penalty from economizer circuit leakage.

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. Correct Answer: A — 50 ppm as an 8-hour TWA (time-weighted average)

OSHA's PEL for carbon monoxide (29 CFR 1910.1000, Table Z-1) is 50 ppm as an 8-hour TWA. NIOSH's REL is 35 ppm TWA and 200 ppm ceiling. ACGIH's TLV-TWA is 25 ppm. CO is produced by incomplete combustion of carbon-containing fuels — diesel generators, forklifts, and gas-fired equipment in enclosed spaces are common industrial CO sources. Stationary engineers must monitor CO levels in generator rooms, boiler rooms, and areas with combustion equipment.

82. Correct Answer: B — Current and past owners and operators of the facility, generators who sent waste to the site, and transporters who selected the disposal site — liability is strict, joint, and several

CERCLA Section 107(a) imposes liability on four categories of PRPs: (1) current owners and operators of the facility, (2) past owners and operators at the time of disposal, (3) generators who arranged for disposal of hazardous substances at the site, and (4) transporters who selected the site. CERCLA liability is retroactive (applies to past disposal), strict (no need to prove negligence), and joint and several (any PRP can be held liable for the full cleanup cost if other PRPs are insolvent or cannot be found).

83. Correct Answer: A — Periodic energy audits and retro-commissioning of base building systems in buildings over 50,000 square feet — to identify and implement energy conservation measures

NYC Local Law 87 requires covered buildings (50,000+ square feet) to perform an energy audit and retro-commissioning (RCx) of base building systems every 10 years. The energy audit identifies and analyzes energy efficiency measures; retro-commissioning verifies that building systems are operating as designed and identifies operational improvements. Reports must be filed with the NYC Department of Buildings. LL87 is part of NYC's Greener, Greater Buildings Plan — aimed at reducing energy consumption and carbon emissions from the city's largest buildings.

84. Correct Answer: D — Is subject to PSM if the facility also handles any other listed highly hazardous chemical above its threshold quantity

OSHA PSM applies when a listed highly hazardous chemical is present above its threshold quantity (TQ). Chlorine's TQ is 1,500 lbs — this facility has only 500 lbs, which is below the TQ. Therefore, chlorine alone does not trigger PSM. However, if the facility also handles other listed chemicals above their respective TQs, those processes are subject to PSM. Each chemical and process is evaluated independently against its own TQ. Below TQ does not trigger PSM for that specific chemical.

85. Correct Answer: C — Hepatitis B vaccination offered at no cost to the employee — and post-exposure evaluation and follow-up after any exposure incident

OSHA 1910.1030 requires employers to: (1) offer hepatitis B vaccination to all employees with occupational exposure at no cost within 10 days of initial assignment; (2) provide post-exposure evaluation and follow-up (including confidential medical evaluation, blood testing, and post-exposure prophylaxis as recommended) after any exposure incident. The standard does not require mandatory HIV testing — testing must be offered but the employee may decline. Bloodborne pathogen training is required annually for all employees with occupational exposure.

86. Correct Answer: C — The State Emergency Response Commission (SERC) and Local Emergency Planning Committee (LEPC) immediately — and to the NRC if the release meets CERCLA reporting requirements

EPCRA Section 304 requires immediate notification to the SERC and LEPC when an EHS is released above its reportable quantity. The notification must include: the chemical name, whether it is an EHS, estimated quantity released, time and duration of release, affected media, health risks, precautions, and contact information. A follow-up written notice is required within 30 days. If the release also meets CERCLA Section 103 reporting requirements, additional notification to the National Response Center (NRC) at 1-800-424-8802 is required.

87. Correct Answer: C — Protect laboratory workers from health hazards associated with hazardous chemicals used in the laboratory — including standard operating procedures, exposure control limits, and emergency procedures

OSHA's Laboratory Safety Standard (29 CFR 1910.1450) applies to laboratories where relatively small quantities of hazardous chemicals are used on a non-production basis. Rather than applying all individual chemical substance standards, the laboratory standard requires employers to develop a Chemical Hygiene Plan (CHP) that includes: standard operating procedures for hazardous chemicals, engineering controls and PPE requirements, criteria for when fume hood use is required, measures to ensure fume hoods function properly, employee information and training, and medical consultation provisions.

88. Correct Answer: D — Identified through a building survey before renovation, abated by a licensed asbestos contractor following EPA NESHAP and NYC DEP regulations, and disposed of as asbestos waste in sealed, labeled bags to a permitted landfill

EPA NESHAP (40 CFR Part 61, Subpart M) requires asbestos surveys before demolition or renovation of facilities that might contain ACM, notification to the EPA/state agency before asbestos removal above threshold quantities, use of proper removal and disposal procedures, and disposal only at permitted solid waste disposal sites in sealed, labeled containers. In NYC, DEP Local Law 76 and NYC Rules Title 15 impose additional requirements — including use of NYC-licensed asbestos contractors, air monitoring during abatement, clearance air testing before re-occupancy, and filing of ACP-7 notifications with the NYC DEP before any asbestos project begins. Asbestos waste must be double-bagged in 6-mil polyethylene bags, labeled with the OSHA asbestos warning label, and transported by a licensed waste hauler to a permitted landfill.

89. Correct Answer: D — Recycling through a universal waste handler or lamp recycler — fluorescent lamps are managed as universal waste under 40 CFR Part 273, which allows more flexible management than full RCRA hazardous waste requirements while ensuring mercury is properly recovered

EPA's Universal Waste Rule (40 CFR Part 273) covers fluorescent lamps, batteries, pesticides, and mercury-containing equipment. Universal waste handlers do not need a RCRA hazardous waste permit — they simply accumulate lamps in closed containers, label them "Universal Waste — Lamp(s)," and send them to a universal waste handler or recycler within one year. Crushing lamps for volume reduction is prohibited without an air permit because it releases mercury vapor. In NYC, DEP rules require lamp recycling regardless of quantity generated.

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

90. Correct Answer: B — All sources of electrical energy to the equipment have been de-energized, locked and tagged out, stored energy has been released or restrained, and absence of voltage has been verified with a properly rated tester — making the equipment safe to touch

NFPA 70E Section 120.1 defines an electrically safe work condition as a state in which the conductor or circuit part to be worked on has been disconnected from energized parts, locked and tagged in accordance with established standards, tested to verify the absence of voltage, and grounded if determined necessary. This is a process — not just de-energizing alone. All six steps of NFPA 70E 120.5 must be completed before the equipment is considered truly safe to work on without electrical PPE.

91. Correct Answer: D — Control the fire hazard from welding, cutting, grinding, and other hot work by requiring a formal review of the work area for combustibles, fire watch assignment, fire suppression equipment placement, and supervisor authorization before work begins

NFPA 51B and most facility hot work programs require a written permit before any hot work commences. The permit process ensures: the work area within 35 feet is cleared of combustibles or combustibles are shielded, sprinkler systems are operational, fire detection is not impaired, a trained fire watch is assigned (during and at least 30–60 minutes after work completion), a charged fire extinguisher is immediately available, and a supervisor has reviewed and authorized the work. Statistical data consistently shows hot work as one of the leading causes of industrial fires.

92. Correct Answer: B — Call 911, do not remove clothing stuck to the burn, cover with a clean dry dressing, treat for shock (lay flat, elevate legs if no spinal injury), and monitor for cardiac arrhythmia — electrical burns are often more severe internally than externally

Electrical injuries are deceptive — the entry and exit wounds may appear minor while internal tissues (muscle, nerves, blood vessels) along the current path sustain severe damage from resistive heating. Cardiac arrhythmia (including delayed onset ventricular fibrillation) can occur hours after the initial shock. Never remove burned clothing stuck to skin — removing it causes additional tissue damage. All electrical burn victims require hospital evaluation even if they appear to feel well after the incident.

93. Correct Answer: C — Electric power generation, transmission, and distribution facilities — including utilities and industrial facilities with similar operations — with specific requirements for working on or near energized high-voltage equipment

OSHA 1910.269 ("Electric Power Generation, Transmission, and Distribution") applies to the operation and maintenance of electric power generation, control, transformation, transmission, and distribution lines and equipment. It covers utility workers, and also applies to industrial facilities whose employees perform similar work on comparable equipment. Key requirements include minimum approach distances for energized conductors, PPE for electrical hazards, protective grounding procedures, and qualified worker training specific to the voltages and equipment involved.

94. Correct Answer: B — Determine the incident energy at the working distance or the appropriate PPE category, establish arc flash and shock protection boundaries, and identify the required PPE for energized electrical work tasks

NFPA 70E Section 130.5 requires an arc flash risk assessment before any person approaches exposed energized electrical conductors or circuit parts that have not been placed in an electrically safe work condition. The assessment must: (1) determine if an arc flash hazard exists, (2) estimate the likelihood of occurrence, (3) estimate the severity (incident energy or PPE category), and (4) determine the arc flash boundary and required PPE. The assessment must be updated when changes affect the available fault current, protective device clearing time, or working distance.

95. Correct Answer: A — 19.5% O₂ — OSHA defines oxygen deficiency as below 19.5% and oxygen enrichment as above 23.5%

OSHA 1910.146 and NIOSH define oxygen-deficient atmosphere as less than 19.5% O₂ by volume and oxygen-enriched atmosphere as greater than 23.5% O₂. Normal atmospheric oxygen is 20.9%. Continuous atmospheric monitors in permit-required confined spaces must alarm at 19.5% O₂ for deficiency — alerting entrants before oxygen levels drop to impairment levels (below 16%) or immediately dangerous levels (below 6%). Oxygen-enriched atmospheres above 23.5% dramatically increase fire and explosion risk and also require immediate evacuation.

96. Correct Answer: D — Ensure a second person is always present who can call for help, initiate rescue, and provide immediate first aid if the primary worker is incapacitated by an electrical shock, arc flash, or other emergency

NFPA 70E and OSHA both recommend or require a second person (attendant) for high-risk electrical tasks. The buddy system ensures that if the primary worker is rendered unconscious by an electrical shock, arc flash, or other injury, someone is immediately present to: call emergency services (911), initiate CPR if the victim is in cardiac arrest, de-energize the circuit if safely possible, and direct emergency responders to the location. A lone worker who suffers cardiac arrest from a shock has dramatically lower survival odds — early CPR within 2–3 minutes is critical.

97. Correct Answer: B — Notify the supervisor and building occupants, evacuate the immediate area, call the fire department, and do not open the panel — opening a potentially arcing panel can cause an arc flash explosion that would injure the responder

A burning smell from an electrical panel indicates a possible active arcing fault, overloaded conductor, or failing component inside — conditions that can produce an arc flash if the panel is opened. The correct response is to treat it as a fire emergency: notify occupants and supervisor, evacuate the immediate area, call the fire department, and allow trained firefighters with proper PPE to assess the situation. Never open a potentially faulted panel without proper arc flash PPE, a qualified electrical worker, and an established emergency response plan.

98. Correct Answer: D — 12 cal/cm² — PPE arc rating must equal or exceed the calculated incident energy per NFPA 70E 130.5(G)

NFPA 70E Section 130.5(G) requires that when the incident energy analysis method is used, the arc-rated PPE selected must have an arc rating (ATPV or EBT) equal to or greater than the calculated incident energy at the working distance. For 12 cal/cm² incident energy, the PPE arc rating must be ≥ 12 cal/cm² — a single-layer arc-rated suit rated at 12 cal/cm² or higher is required. Using the PPE category method, 12 cal/cm² falls within PPE Category 2 (8–25 cal/cm²) — but when incident energy analysis is performed, the actual calculated value governs.

99. Correct Answer: B — A designated primary authorized employee to apply a group lockout hasp on each energy isolation point — each worker in the group applies their personal lock to the hasp(s), and the primary authorized employee verifies all energy has been controlled before work begins

OSHA 1910.147(f)(3) addresses group LOTO procedures. The primary authorized employee applies a personal lock to each group lockout hasp at each energy isolation point — one hasp per energy source. Each worker in the group then applies their individual personal lock to the group hasp(s). No work begins until the primary authorized employee verifies that all energy sources have been isolated and all workers have applied their locks. When a worker completes their portion of the work, they remove only their personal lock — the equipment remains locked out until every worker removes their lock.

100. Correct Answer: B — Establishing and enforcing a written electrical safety program with a clear requirement to de-energize equipment before working on it — with energized work as the rare, justified exception rather than common practice

NFPA 70E Section 110.1 requires employers to establish, document, and implement an electrical safety program. The single most effective administrative control for preventing electrical fatalities is a strong cultural and procedural commitment to the hierarchy of risk controls — with elimination (de-energizing) as the first and preferred control, not arc flash PPE. Statistics consistently show that facilities with strong "de-energize first" cultures have dramatically lower electrical injury rates than those that routinely permit energized work. PPE, labels, and training are all important — but none substitute for simply turning the equipment off.