PRACTICE EXAM 13: STATIONARY ENGINEER (ELECTRIC) SIMULATION — 100 QUESTIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. A 240V single-phase circuit supplies a 4,800W resistive load. The current drawn is?

A. 10A

B. 40A

C. 24A

D. 20A

2. The time constant (τ) of a series RL circuit with R = 50Ω and L = 2H is?

A. 100 seconds

B. 0.04 seconds

C. 25 seconds

D. 4 seconds

3. The voltage across a 40μF capacitor charged to 300V stores how much energy?

A. 1.8 joules

B. 0.9 joules

C. 3.6 joules

D. 12,000 joules

4. Which of the following correctly describes Fleming's Left-Hand Rule for electric motors?

A. The thumb points in the direction of motion (force), the index finger in the direction of the magnetic field, and the middle finger in the direction of current — the three are mutually perpendicular

B. The thumb points in the direction of current, the index finger in the direction of force, and the middle finger in the direction of the magnetic field

C. The thumb points in the direction of the magnetic field, the index finger in the direction of motion, and the middle finger in the direction of current

D. The three fingers represent voltage, current, and resistance respectively

5. In a balanced three-phase wye system, if phase A voltage is 277V at 0°, what is the phase B voltage?

A. 277V at +120°

B. 277V at −60°

C. 277V at +60°

D. 277V at −120°

6. A transformer has 400 primary turns and 80 secondary turns. If the primary current is 5A, the secondary current is?

A. 1A

B. 100A

C. 40A

D. 25A

7. The impedance of a series circuit with R = 8Ω, XL = 15Ω, and XC = 9Ω is?

A. 32Ω

B. 8Ω

C. 10Ω

D. 14Ω

8. In an AC circuit, the relationship between RMS voltage and peak voltage is?

A. $V_{RMS} = V_{peak} \div \sqrt{2}$ — the RMS value equals 70.7% of the peak value

B. $V_{RMS} = V_{peak} \times \sqrt{2}$

C. $V_{RMS} = V_{peak} \times 2$

D. $V_{RMS} = V_{peak} \div 2$

9. The purpose of a varistor (MOV — Metal Oxide Varistor) in an electrical circuit is to?

A. Regulate current at a constant level regardless of voltage variation

B. Filter harmonic frequencies from the power supply

C. Increase circuit impedance during surges

D. Clamp voltage transients by conducting heavily when voltage exceeds the MOV's clamping voltage — protecting sensitive circuit components from overvoltage damage

10. In a three-phase system, the power factor can be measured using the two-wattmeter method. If W1 = 8 kW and W2 = 4 kW, the total power and power factor are?

A. Total power = 12 kW; $PF = \cos(\arctan(\sqrt{3} \times (W1-W2)/(W1+W2))) = \cos(\arctan(\sqrt{3} \times 4/12)) = \cos(30°) = 0.866$

B. Total power = 4 kW; PF = 0.5

C. Total power = 12 kW; PF = 1.0

D. Total power = 8 kW; PF = 0.75

11. The phenomenon of "ferroresonance" in power systems occurs when?

A. A transformer operates above its rated kVA for extended periods

B. The nonlinear magnetizing inductance of a transformer resonates with a system capacitance — producing overvoltages, chaotic behavior, and sustained oscillations that can damage transformers, surge arresters, and connected equipment

C. Two generators operating in parallel develop a phase difference

D. A transformer secondary is accidentally open-circuited under full primary voltage

12. A synchronous motor operating at leading power factor is said to be?

A. Under-excited — absorbing reactive power from the system

B. Over-excited — supplying reactive power to the system, acting as a capacitor

C. At unity power factor — neither absorbing nor supplying reactive power

D. Operating in the motoring mode only — synchronous motors cannot supply reactive power

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

13. The NEC requires that all 125V, 15A and 20A receptacles in bathrooms, garages, outdoors, crawl spaces, unfinished basements, kitchens, and boat houses be protected by?

A. Ground fault circuit interrupters (GFCIs)

B. Arc fault circuit interrupters (AFCIs)

C. Both GFCI and AFCI protection simultaneously

D. Tamper-resistant receptacles only

14. The maximum number of current-carrying conductors permitted in a conduit before ampacity derating begins per NEC 310.15(C) is?

A. Three — any more than three current-carrying conductors in a raceway requires derating

B. Four

C. Six

D. Two

15. Type MC cable used in a cable tray in a wet location must use?

A. Standard MC cable — all MC cable is rated for wet locations

B. MC cable with a moisture- and corrosion-resistant outer jacket listed for use in wet locations

C. Rigid metal conduit instead of MC cable in all wet locations

D. MC cable with THWN conductors inside standard MC armor

16. The NEC working space requirements for electrical panels apply to the area?

A. In front of the equipment from the floor to a height of 6.5 feet (or the height of the equipment if greater) and to the width of the equipment or 30 inches, whichever is greater

B. On all four sides of the electrical equipment equally

C. Only directly in front of the panel door opening

D. Within 12 inches of any energized bus bar inside the panel

17. Arc fault circuit interrupters (AFCIs) are required by the NEC for branch circuits supplying?

A. All outdoor receptacles only

B. Dwelling unit bedrooms, living rooms, hallways, kitchens, and virtually all dwelling unit areas — NEC 2020 210.12 extended AFCI protection to nearly all dwelling unit branch circuits

C. Commercial kitchen equipment only

D. Only circuits supplying electronics and computer equipment

18. The purpose of a "listed" overcurrent protective device is that it has been?

A. Approved by the local authority having jurisdiction (AHJ) only

B. Manufactured by a UL-listed company

C. Evaluated by a nationally recognized testing laboratory (NRTL) such as UL, ETL, or CSA and found to comply with applicable product safety standards — ensuring reliable operation at rated values

D. Tested in the field and found to operate within 10% of its rated value

19. In a motor branch circuit, the branch circuit short circuit and ground fault protective device (fuse or breaker) is permitted to be sized larger than the conductor ampacity because?

A. Motors always run below their nameplate current rating

B. Motors have high starting (inrush) current that would trip a device sized for the conductor ampacity — the larger device permits the motor to start while the overload relay protects the conductor during running conditions

C. The NEC requires oversized protection for all motor circuits regardless of starting current

D. The feeder supplying the motor branch circuit provides backup protection

20. The maximum length of a flexible cord used as a wiring method from a permanently installed junction box to a piece of utilization equipment is?

A. 3 feet

B. 6 feet

C. 10 feet

D. Flexible cords are not permitted as a wiring method for permanent installations — they are limited to specific uses listed in NEC 400.7

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

A. 0.91

B. 0.82

C. 0.71

D. 0.58

22. A "qualified person" per OSHA 1910.399 must be capable of?

A. Installing new electrical equipment without supervision

B. Working on energized circuits above 600V with appropriate supervision only

C. Performing all NEC code calculations independently

D. Performing electrical work safely on electrical equipment and recognizing the hazards involved — qualification is determined by the nature of the work and the electrical hazards present, not solely by credentials

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

23. The purpose of a tap fuse on a transformer secondary is to?

A. Limit the available fault current at the secondary terminals

B. Protect the secondary conductors from the transformer's available fault current — the tap fuse clears secondary faults before conductor damage occurs, supplementing or replacing remote overcurrent protection

C. Prevent transformer inrush current from operating the primary fuse

D. Provide overvoltage protection for the secondary winding

24. In a unit substation, the typical arrangement from the utility interface to the load side is?

A. Primary disconnect switch → primary fuses or breaker → transformer → secondary main breaker → distribution section (feeder breakers)

B. Primary fuses → transformer → secondary distribution → primary disconnect

C. Transformer → primary disconnect → secondary main breaker → primary fuses

D. Secondary distribution → transformer → primary disconnect → utility metering

25. The purpose of a ground check monitor on a medium-voltage mining cable is to?

A. Measure the insulation resistance of each phase conductor

B. Monitor the cable's temperature for overload protection

C. Continuously monitor the continuity of the equipment grounding conductor — if the ground conductor opens, the monitor trips the power circuit before the equipment can be touched with a broken ground path

D. Verify proper phase sequence of the supply to the mining equipment

26. A 13.8kV feeder circuit breaker has an interrupting rating of 40 kA symmetrical. This means?

A. The breaker can carry 40 kA continuously without damage

B. The breaker can safely interrupt (open under) a fault current of up to 40 kA RMS symmetrical without failure — the interrupting rating must exceed the available fault current at the point of installation

C. The breaker requires 40 kA of fault current to operate

D. The breaker's close-and-latch rating is 40 kA

27. The purpose of reactive power compensation (capacitor banks or STATCOMs) at a substation is to?

A. Reduce the real power losses in the transmission line only

B. Support bus voltage, reduce reactive current flow in transmission lines, improve power factor, and increase the real power transfer capacity of the transmission system

C. Protect transmission lines from lightning overvoltages

D. Provide backup real power during generator outages

28. An autotransformer differs from a two-winding transformer in that?

A. An autotransformer uses iron cores while two-winding transformers use air cores

B. An autotransformer has only one winding serving as both primary and secondary — part of the winding is common to both input and output circuits, providing no galvanic isolation between primary and secondary

C. An autotransformer can only step voltage down, not up

D. An autotransformer is limited to single-phase applications only

29. In a substation, a "ring bus" configuration provides the advantage that?

A. It reduces the total number of circuit breakers required compared to a breaker-and-a-half scheme

B. Each bus section can be isolated without interrupting any other section

C. Any single bus element or circuit breaker can be taken out of service without interrupting service to any circuit — each circuit is connected between two breakers in the ring, and the ring can be opened at any point while maintaining all circuits energized

D. It provides the highest fault current interrupting capacity of any bus configuration

30. The purpose of a current-limiting reactor (series reactor) installed on a bus tie or feeder is to?

A. Increase the available fault current for faster fuse operation

B. Provide voltage regulation on long distribution feeders

C. Reduce the available fault current at downstream buses — limiting the fault current that equipment must be rated to interrupt and withstand during fault conditions

D. Filter harmonic currents from variable frequency drives

31. In power system protection, the term "coordination" means?

A. Multiple relays operating simultaneously on all faults regardless of location

B. The overcurrent protective devices are selected and set so that the device nearest the fault operates first — clearing the fault with the minimum interruption of service to other loads

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

D. The primary relay and backup relay have identical settings

32. The purpose of a transformer neutral grounding resistor (NGR) in a medium-voltage wye-grounded system is to?

A. Improve transformer efficiency during light load conditions

B. Provide a return path for load unbalance current

C. Prevent transformer ferroresonance during switching

D. Limit the ground fault current contribution from the transformer to a safe level — protecting the transformer core and windings from damage during single-phase-to-ground faults

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

33. A generator's voltage regulation is defined as?

A. The percentage change in field current from no-load to full load

B. The percentage change in terminal voltage from no-load to full-load at constant speed and field current: $VR = (V_{NL} - V_{FL}) \div V_{FL} \times 100\%$

C. The maximum voltage deviation permitted during load transients

D. The AVR's response time in milliseconds from load application to voltage restoration

34. The purpose of a motor's service factor (SF) is to?

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

B. Specify the motor's maximum allowable starting current

C. Indicate the permissible overload multiplier — a motor with SF = 1.15 can operate continuously at 115% of its nameplate HP under specific conditions without exceeding its thermal rating

D. Establish the motor's minimum efficiency at full load

35. In a three-phase AC induction motor, torque is produced by the interaction between?

A. The rotating magnetic field produced by the stator currents and the currents induced in the rotor conductors by the rotating field — the force on the rotor conductors (F = BIL) creates the torque that drives the load

B. The rotor's permanent magnets and the stator's rotating field

C. The stator winding resistance and the rotor's inertia

D. The applied voltage and the rotor's mechanical speed directly

36. The purpose of a motor's frame designation (NEMA frame number) is to?

A. Specify the motor's electrical characteristics including voltage and frequency rating

B. Define the motor's maximum ambient operating temperature

C. Specify the motor's protection class against dust and moisture

D. Define the physical dimensions of the motor — shaft height, shaft diameter, bolt circle, and overall dimensions — allowing standardized mounting and replacement without custom fabrication

37. A soft starter reduces motor starting current by?

A. Connecting starting resistors in series with the motor during acceleration

B. Gradually increasing the voltage applied to the motor during the starting period using back-to-back SCRs (silicon controlled rectifiers) — reducing starting torque and current proportional to the reduced voltage

C. Using an autotransformer to reduce starting voltage in fixed steps

D. Switching motor winding connections from wye to delta during starting

38. The purpose of a thermal overload relay's "reset" function (manual vs. automatic) is to?

A. Clear the relay's fault memory after a trip event

B. Restore the relay's output contact to the closed (motor-run) position after an overload trip — manual reset requires an operator to physically reset the relay, preventing automatic restart after an overload, while automatic reset allows restart after the relay cools

C. Recalibrate the relay's trip current setting after a trip

D. Test the relay's trip function without interrupting the motor circuit

39. A 480V, 3-phase, 4-wire wye system develops a single-phase-to-neutral fault on phase A. The fault current is limited only by the phase A conductor impedance of 0.5Ω. The fault current is approximately?

A. 480A

B. 240A

C. 960A

D. 554A

40. In a motor control circuit, a "two-wire control" scheme differs from a "three-wire control" scheme in that two-wire control?

A. Uses two separate control transformers for redundancy

B. Requires two operators to simultaneously press start buttons

C. Uses a maintained-contact device (such as a float switch, pressure switch, or thermostat) that holds the contactor closed automatically — allowing automatic restart after a power interruption, unlike three-wire control which requires manual restart

D. Provides two independent stop buttons for safety

41. The purpose of a reactor (inductor) connected in series with a power capacitor bank is to?

A. Detune the capacitor bank from system harmonic frequencies — preventing the capacitor from amplifying harmonic voltages and forming resonant circuits with transformer inductance that amplify harmonic currents

B. Reduce the capacitor's reactive power output

C. Protect the capacitor from overvoltage during switching

D. Improve the capacitor's power factor correction effectiveness

42. A motor nameplate reads: 480V, 3PH, 60Hz, 50HP, 1,775 RPM, 57A FLA, SF 1.15, Code G. The "Code G" designation indicates?

A. The motor's insulation class is Grade G

B. The motor's efficiency rating category

C. The motor's starting torque classification

D. The motor's locked rotor kVA per horsepower code — Code G indicates 5.6–6.3 kVA/HP starting kVA, used to select the branch circuit overcurrent protective device

43. In a DC motor, the function of the commutator is to?

A. Regulate the field current to control motor speed

B. Provide electrical connection between the rotor winding and the external circuit through the brushes

C. Convert the alternating current induced in the rotor conductors to direct current at the motor's output terminals — maintaining unidirectional torque by reversing the rotor connections as each armature coil passes through the neutral axis

D. Both B and C — the commutator serves both mechanical switching and rectification functions simultaneously

43. In a DC motor, the function of the commutator and brush assembly is to?

A. Filter ripple from the DC supply before it reaches the armature winding

B. Regulate field excitation automatically based on load changes

C. Maintain continuous electrical contact between the stationary external circuit and the rotating armature — reversing the armature coil connections at the neutral axis to maintain unidirectional torque

D. Connect and disconnect armature winding sections for speed control

44. The purpose of regenerative braking in a VFD-controlled motor system (with an active front end rectifier) is to?

A. Provide emergency braking when the VFD loses power

B. Limit motor deceleration to a safe mechanical rate only

C. Protect the motor bearings from high-speed deceleration forces

D. Return the kinetic energy of the decelerating motor and load back to the AC supply as real power — rather than dissipating it as heat in a braking resistor, improving overall system energy efficiency

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

45. The purpose of a dielectric absorption ratio (DAR) test on electrical insulation is to?

A. Compare the 30-second to 1-minute insulation resistance readings — a ratio below 1.25 indicates wet, contaminated, or deteriorated insulation that cannot properly polarize, while a ratio above 1.25 indicates good insulation

B. Measure the insulation's capacitance per unit length

C. Determine the insulation's maximum operating temperature

D. Verify the insulation's mechanical flexibility after aging

46. An oscilloscope trace of a VFD output voltage shows voltage spikes exceeding 1,200V on a 480V system. These spikes are caused by?

A. Transformer saturation from VFD harmonic currents

B. Capacitive coupling between VFD output phases

C. Transmission line reflection effects — when the VFD's IGBT switching speed (dV/dt) exceeds the cable's propagation characteristics, voltage waves reflect at the motor terminals, doubling the peak voltage. Long cables between VFD and motor worsen this effect

D. Motor winding resonance at the VFD carrier frequency

47. The purpose of contact resistance testing (micro-ohm testing) on circuit breaker contacts is to?

A. Verify the breaker's interrupting rating has not been degraded by previous fault interruptions

B. Measure the breaker's contact spring force

C. Test the breaker's insulation resistance between phases

D. Verify low contact resistance (typically less than 50–200 μΩ depending on breaker rating) — high contact resistance indicates eroded, oxidized, or misaligned contacts that will overheat under load current and may fail to carry rated current

48. When interpreting transformer oil dissolved gas analysis (DGA), the presence of high levels of acetylene (C_2H_2) indicates?

A. High-energy arcing in the transformer — acetylene is only produced by very high temperature arcing (above 700°C) such as occurs during internal arc discharge faults, contact arcing, or tap changer arcing under oil

B. Thermal degradation of the oil at moderate temperatures

C. Cellulose (paper) insulation degradation from moisture

D. Normal aging gases from routine thermal operation

49. A megger test on a 480V motor winding reads 50 MΩ at 500V DC after 1 minute. This reading indicates?

A. Acceptable insulation — IEEE 43 suggests a minimum of 1 MΩ for motors up to 1 kV; 50 MΩ well exceeds this minimum and indicates good insulation condition

B. Marginal insulation requiring immediate rewinding

C. Failed insulation — the reading should exceed 100 MΩ for any serviceable motor

D. The test voltage is too low — 500V DC cannot detect insulation deterioration in 480V motors

50. The purpose of a relay coordination study is to?

A. Set all relays to trip at the same time for uniform system protection

B. Verify that relay settings comply with NEC minimum requirements

C. Test relays under actual fault current conditions to verify trip times

D. Determine relay pickup and time-delay settings that ensure the relay nearest a fault operates first while upstream relays serve as backup — maintaining maximum service continuity while clearing faults selectively

51. A three-phase motor draws unequal currents of 45A, 43A, and 47A on the three phases. The percent current unbalance using the NEMA method is?

A. 4.4%

B. 2.2%

C. 4.7% — NEMA defines % unbalance = (maximum deviation from average ÷ average) × 100; average = (45+43+47)/3 = 45A; max deviation = 47−45 = 2A; unbalance = (2/45) × 100 = 4.4%

D. 9.3%

52. The purpose of a power system harmonic study is to?

A. Calculate the available fault current at each bus in the system

B. Assess the impact of harmonic-producing loads on power quality, identify resonant frequencies, evaluate transformer and conductor heating from harmonics, and design mitigation measures (filters, reactors) to comply with IEEE 519

C. Determine the optimal capacitor bank size for power factor correction only

D. Verify protective relay coordination under harmonic fault conditions

53. When performing a ground fault test on a medium-voltage switchgear assembly, the test verifies?

A. The insulation resistance between phase conductors

B. The continuity of the main bus conductors

C. The accuracy of the metering CTs and PTs

D. The operation of the ground fault sensing relay and trip circuit — confirming the relay detects the simulated ground fault at the correct sensitivity level and correctly trips the appropriate breaker within the specified time

54. The purpose of an insulation power factor (tan delta) test on a transformer is to?

A. Measure the transformer's core loss at rated voltage

B. Verify the transformer's turns ratio under load conditions

C. Assess the transformer's mechanical condition under short circuit forces

D. Measure the dielectric losses in the insulation system — a high insulation power factor (tan δ above 0.5%) indicates contamination, moisture absorption, or aging of the solid insulation and oil, providing early warning of insulation deterioration before failure

MECHANICAL EQUIPMENT (Questions 55–63)

55. The purpose of a pump's wear rings (casing rings and impeller rings) is to?

A. Protect the pump shaft from corrosion at the stuffing box

B. Provide a mechanical seal between the impeller and casing

C. Support the impeller weight on the pump shaft

D. Minimize internal recirculation (leakage) from the high-pressure discharge back to the low-pressure suction — maintaining pump efficiency as clearances are controlled by replaceable rings rather than requiring replacement of the entire casing or impeller

56. In a gas turbine, the compression ratio refers to?

A. The ratio of turbine inlet temperature to compressor inlet temperature

B. The ratio of turbine output power to compressor input power

C. The ratio of exhaust gas pressure to inlet air pressure

D. The ratio of compressor discharge pressure to compressor inlet pressure — higher compression ratios increase thermal efficiency and power output, but are limited by compressor surge margin and turbine inlet temperature constraints

57. The purpose of a centrifugal compressor's anti-surge control system is to?

A. Limit the compressor's maximum discharge pressure

B. Prevent the compressor motor from overloading during startup

C. Detect the approach to surge (the point of flow reversal and pressure collapse) and open a recycle or blow-off valve to maintain flow above the minimum stable flow rate — preventing the violent pressure oscillations that cause surge

D. Control compressor speed to maintain constant discharge pressure

58. In a boiler system, the function of a modulating feedwater control valve is to?

A. Maintain a constant water level in the boiler drum by continuously adjusting feedwater flow to match the steam flow leaving the boiler — preventing both low water (causing overheating) and high water (causing carryover of water into the steam lines)

B. Control steam pressure by throttling feedwater flow

C. Prevent feedwater pump cavitation during low load operation

D. Regulate feedwater temperature entering the economizer

59. The purpose of a lube oil cooler on a large rotating machine is to?

A. Heat the oil before startup to reduce viscosity for easier pump startup

B. Remove heat absorbed by the oil from bearing friction and journal losses — maintaining oil temperature within the specified operating range for proper viscosity and film thickness, preventing bearing damage from overheated, thinned oil

C. Filter particulates from the oil before it reaches the bearings

D. Maintain oil pressure constant regardless of temperature variation

60. A reciprocating air compressor's intercooler (between stages) serves to?

A. Lubricate the piston rings in the high-pressure stage

B. Remove moisture from the compressed air between stages

C. Increase the pressure of the air between stages

D. Cool the partially compressed air between compression stages — reducing the inlet temperature to the next stage, which reduces the work of compression (approaching isothermal compression), increases air density, and reduces thermal stress on the high-pressure cylinders

61. The purpose of a vibration isolator (spring or rubber mount) under rotating equipment is to?

A. Prevent machinery vibration from transmitting to the building structure — protecting the structure from fatigue and preventing vibration from interfering with sensitive nearby equipment or creating noise complaints

B. Reduce vibration amplitude at the equipment's operating speed

C. Replace the need for precision shaft alignment

D. Protect the equipment from building-borne vibration caused by other machinery

62. In a cooling tower, the "cycles of concentration" refers to?

A. The number of times per hour the cooling tower recirculates its total water volume

B. The ratio of blowdown flow to makeup water flow

C. The ratio of dissolved solids concentration in the recirculating water to the concentration in the makeup water — higher cycles reduce makeup water consumption but increase scale and corrosion potential

D. The number of cooling passes each water molecule makes through the tower fill

63. A steam trap that continuously discharges steam (fails open) causes?

A. Excessive condensate buildup in the steam system

B. Water hammer in the steam supply header

C. Energy waste from loss of live steam — the trap is passing steam directly to the condensate return system or atmosphere, wasting the heat energy that should remain in the steam distribution system

D. Pressure drop in the condensate return system only

FLUID SYSTEMS (Questions 64–72)

64. In a variable air volume (VAV) HVAC system, the VAV terminal box controls?

A. The volume of supply air delivered to the zone by modulating a damper — maintaining zone temperature by varying airflow rather than air temperature, reducing fan energy at part load

B. The supply air temperature to the zone only

C. The return air flow from the zone back to the air handling unit

D. The static pressure in the main supply duct

65. The purpose of a pressure relief valve on a hot water heater is to?

A. Regulate the hot water supply pressure to fixtures

B. Open and discharge water if temperature exceeds 210°F or pressure exceeds the rated setting (typically 150 PSI) — preventing the water heater from becoming a pressure vessel explosion hazard from failed thermostatic controls

C. Prevent cold water from entering the hot water system

D. Control the rate of water heating during recovery

66. In a chilled water system, "free cooling" (waterside economizer) is possible when?

A. The chiller COP exceeds 6.0 at full load

B. The outdoor wet-bulb temperature is low enough that cooling tower water is sufficiently cool to directly (or nearly directly) satisfy the building cooling load — bypassing or supplementing the chiller and saving compressor energy

C. The building load is less than 50% of design capacity

D. The chilled water return temperature exceeds the design setpoint

67. The purpose of a two-way control valve in a hydronic system versus a three-way control valve is that a two-way valve?

A. Allows flow in both directions through the valve body

B. Varies the total flow through the system as it modulates — creating a variable flow system that reduces pump energy at part load, while a three-way valve diverts flow between two paths maintaining constant total flow

C. Provides better temperature control accuracy than a three-way valve

D. Requires a larger valve body for the same flow coefficient (Cv)

68. The purpose of a strainer upstream of a control valve is to?

A. Reduce the pressure drop across the control valve

B. Remove particulates from the fluid that would damage the valve seat and plug — protecting the valve's tight shutoff capability and preventing erosion of close-clearance valve trim

C. Reduce fluid velocity before the valve to prevent cavitation

D. Filter biological growth from the cooling water before the valve

69. In a steam system, superheat refers to?

A. The condition of steam above its condensation temperature at a given pressure — superheated steam contains more energy per pound than saturated steam and resists condensation during transmission, preventing water hammer

B. The steam temperature at the boiler safety valve setpoint

C. The excess heat energy stored in the boiler drum refractory

D. The temperature rise of feedwater in the economizer

70. The purpose of a cooling tower "blowdown" (bleed-off) is to?

A. Remove air from the cooling tower basin during startup

B. Discharge a portion of the recirculating water to prevent the buildup of dissolved solids, scale-forming minerals, and corrosion products that concentrate as water evaporates — maintaining the cycles of concentration within acceptable limits

C. Test the cooling tower's emergency overflow capacity

D. Clean the cooling tower fill media during operation

71. In a pneumatic control system, the standard instrument air pressure range for control signals is?

A. 3–15 PSI — the standard pneumatic control signal range where 3 PSI represents 0% of the control range and 15 PSI represents 100%

B. 0–30 PSI

C. 5–20 PSI

D. 10–25 PSI

72. The purpose of a heat exchanger's "approach temperature" specification is to?

A. Define the maximum allowable temperature of the hot fluid entering the exchanger

B. Specify the minimum allowable cold fluid outlet temperature

C. Define the required flow rate through the heat exchanger

D. Define the minimum temperature difference between the hot fluid outlet and the cold fluid inlet — a smaller approach temperature indicates a more effective (and more expensive) heat exchanger; a larger approach means lower capital cost but reduced thermal effectiveness

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

73. The purpose of a "equipment grounding conductor" (EGC) in portable electric tools is to?

A. Provide a low-resistance path for fault current — if insulation fails and the tool's metal frame becomes energized, fault current flows through the EGC to ground, tripping the branch circuit overcurrent device and preventing electrocution of the user

B. Reduce the tool's electrical noise for sensitive electronics nearby

C. Provide a reference ground for the tool's electronic speed control

D. Connect the tool to the workpiece for better electrical conductivity

74. When selecting wire rope for a rigging application, the designation "6 × 37" means?

A. The rope has a working load limit of 6 tons and 37 feet maximum length

B. The rope has 6 outer strands and 37 wires per strand — more wires per strand increases flexibility but reduces abrasion resistance compared to fewer, larger wires

C. The rope is rated for 6,370 lbs breaking strength

D. The rope has 6 strands with 37 wires each — more wires per strand provides greater flexibility but less abrasion resistance than fewer, larger wires (such as 6×19 construction)

75. The purpose of a conduit sealing fitting (EYS or EYM fitting) in a hazardous location is to?

A. Provide a watertight seal at outdoor conduit entries to prevent rainwater infiltration

B. Allow conduit thermal expansion without stressing the conduit connections

C. Create a mechanical barrier to prevent conduit from being pulled out of enclosures

D. Prevent the passage of gases, vapors, or flames from a hazardous area through the conduit into a non-hazardous area or explosion-proof enclosure — required within 18 inches of explosion-proof equipment entries per NEC 501.15

76. The safe working load (SWL) or working load limit (WLL) of a rigging component is?

A. The component's breaking strength

B. The maximum load the component can withstand before permanent deformation

C. The maximum load the component is rated to lift in normal rigging practice — typically the breaking strength divided by a design factor (safety factor) of 4:1 to 5:1 for rigging hardware

D. The component's rated load at a 45° sling angle

77. When using a torque wrench to tighten electrical bus bar connections, the purpose of torquing to specification is to?

A. Achieve sufficient contact area between the bus bars and hardware only

B. Prevent thread stripping on the hardware

C. Satisfy the insurance inspection requirement for connection documentation

D. Ensure adequate contact pressure for low-resistance connections without overstressing the bus bar material, hardware, or equipment terminals — undertorquing causes high-resistance connections and overheating; overtorquing cracks insulators and distorts bus bars

78. The purpose of a pipe wrench's adjustable jaw design is to?

A. Allow the wrench to be used in both tightening and loosening directions without adjustment

B. Grip round pipe surfaces by self-tightening under load — the floating jaw moves slightly under force, increasing grip as more torque is applied, preventing slippage on smooth cylindrical surfaces

C. Accommodate pipe sizes from 1/8" to 36" with a single tool

D. Prevent damage to chrome-plated or polished pipe fittings

79. The correct procedure for inspecting a chain hoist before use includes?

A. Checking the load chain for twisted, kinked, worn, or cracked links; verifying the hook latch operates correctly; inspecting the hook for cracks, deformation, or twist; verifying the brake holds under load; and confirming the rated capacity tag is present and legible

B. Lubricating all chain links and hooks before each use

C. Load testing the hoist to 125% WLL before each use

D. Visually checking the outer chain links only

80. A laser level used for conduit alignment must be?

A. Calibrated annually by the manufacturer

B. Operated only by a licensed surveyor in commercial applications

C. Used in conjunction with traditional levels for all conduit runs

D. Verified for level accuracy by checking against a known reference before use — even new laser levels can be out of calibration from shipping or job site impacts

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. OSHA's Hazard Communication Standard (HazCom 2012) requires employers to?

A. Maintain an up-to-date SDS for each hazardous chemical in the workplace, label all containers of hazardous chemicals, and train employees on chemical hazards and protective measures

B. Conduct annual industrial hygiene air sampling for all listed chemicals

C. Submit annual chemical inventory reports to OSHA

D. Replace all hazardous chemicals with safer alternatives within 5 years

82. The purpose of a "Job Safety Analysis" (JSA) or "Activity Hazard Analysis" (AHA) is to?

A. Document the cost of workplace accidents for insurance purposes

B. Identify hazards at each step of a job task and specify controls to reduce risk before the work begins — involving the workers who perform the task to ensure all hazards are identified from practical experience

C. Satisfy OSHA injury recordkeeping requirements under 29 CFR 1904

D. Replace the need for general safety training by providing task-specific instructions only

83. Under NYC Local Law 196 (2017), workers on most construction sites in NYC must obtain?

A. A Site Safety Training (SST) card — requiring 40 hours of OSHA-approved safety training for workers (with exceptions for supervisory personnel who need 62 hours) — the card must be carried on the job site at all times

B. A NYC Buildings Department contractor license

C. An OSHA 30-hour general industry card

D. A NYC Fire Department hot work permit

84. The OSHA Process Safety Management (PSM) standard applies to facilities that?

A. Handle any amount of toxic chemicals listed in OSHA 1910.119 Appendix A

B. Operate boilers above 15 PSI steam pressure

C. Use chlorinated solvents in quantities above 55 gallons

D. Have a listed highly hazardous chemical present in a process in a quantity at or above the threshold quantity specified in OSHA 1910.119 Appendix A — requiring a comprehensive process safety management program

85. The primary health hazard from chronic exposure to hexavalent chromium (Cr VI), found in some welding fumes and surface coatings, is?

A. Liver damage and jaundice from metal accumulation

B. Peripheral neuropathy from nerve damage

C. Lung cancer, nasal septum ulceration and perforation, and sensitization dermatitis — OSHA's PEL for Cr(VI) is 5 $\mu g/m^3$ as an 8-hour TWA

D. Kidney failure from chromium accumulation in renal tubules

86. The EPA's SPCC (Spill Prevention, Control, and Countermeasure) rule applies to facilities that?

A. Store more than 55 gallons of any petroleum product

B. Have underground storage tanks for petroleum products only

C. Are located within 100 feet of a navigable waterway

D. Store petroleum products in quantities above 1,320 gallons aboveground (or 42,000 gallons underground) and have a reasonable expectation that a discharge could reach navigable waters — requiring a written SPCC plan with containment measures

87. The purpose of a Safety Data Sheet's Section 8 (Exposure Controls/Personal Protection) is to?

A. List the chemical's physical and chemical properties

B. Provide occupational exposure limits (OSHA PELs, ACGIH TLVs), required engineering controls (ventilation), and recommended PPE for handling the chemical — giving workers the specific protection information needed for their tasks

C. Describe first aid measures for exposure incidents

D. List the chemical's reactivity hazards and incompatible materials

88. Under EPA's Clean Water Act NPDES permit program, a facility discharging industrial process wastewater to a municipal sewer system must comply with?

A. Secondary treatment standards equivalent to a municipal wastewater treatment plant

B. Pretreatment standards — removing pollutants that would interfere with the POTW's treatment processes, pass through untreated to the receiving water, or contaminate the POTW's biosolids before discharge to the sewer

C. Stormwater permit requirements for all process discharges

D. Zero discharge requirements for all listed toxic pollutants

89. The purpose of a facility's chemical inventory under EPCRA Section 312 (Tier II reporting) is to?

A. Document chemical purchases for tax deduction purposes

B. Satisfy OSHA HazCom inventory requirements annually

C. Provide state and local emergency planning organizations and fire departments with information about hazardous chemicals stored at the facility above threshold quantities — enabling emergency planners to prepare appropriate response plans

D. Report chemical releases to the EPA's TRI database

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

90. The hierarchy of controls for electrical hazard mitigation in order from most to least preferred is?

A. PPE → Administrative controls → Engineering controls → Substitution → Elimination

B. Administrative controls → Engineering controls → PPE → Substitution → Elimination

C. Elimination → Substitution → Engineering controls → Administrative controls → PPE

D. Engineering controls → Elimination → PPE → Administrative controls → Substitution

91. Under OSHA 1910.147, the minimum content of an equipment-specific LOTO procedure must include?

A. The specific steps for shutting down, isolating, blocking, and securing the equipment; the location and type of each energy isolating device; the type and magnitude of each energy source; and the method for verifying that energy has been isolated — for each piece of equipment covered

B. Only the equipment name and location of the main disconnect

C. The names of all authorized employees permitted to perform LOTO on the equipment

D. The date of the last LOTO procedure audit and revision

92. The purpose of a confined space "entry supervisor" per OSHA 1910.146 is to?

A. Operate the mechanical ventilation system during entry

B. Perform atmospheric testing before and during entry

C. Rescue the entrant if conditions deteriorate

D. Know the hazards associated with the permit space, verify that entry conditions are acceptable, authorize entry, ensure the permit is posted, oversee the permit system, and cancel the permit when the work is complete or conditions change

93. The minimum required PPE for a qualified worker performing voltage testing on an energized 480V motor control center using a CAT III rated test instrument includes?

A. Safety glasses and leather gloves only

B. Arc-rated face shield and hard hat only

C. Safety glasses or face shield, rubber insulating gloves rated for the voltage, and arc-rated PPE appropriate for the incident energy or PPE category at the MCC — per NFPA 70E shock and arc flash hazard requirements

D. Chemical splash goggles and FR clothing only

94. Under NFPA 72, a fire alarm system's annual inspection must include?

A. Testing only the initiating devices (smoke and heat detectors) — notification appliances are tested every 5 years

B. Testing all system components including initiating devices, notification appliances, control panels, power supplies, and supervisory devices — per NFPA 72 Table 14.4.5 required frequencies

C. Visual inspection only — full functional testing is required only every 5 years

D. Testing the fire alarm control panel only — field devices are tested by the sprinkler contractor

95. The purpose of a safety interlock bypass switch on a piece of industrial machinery is to?

A. Permanently disable safety interlocks for maintenance access

B. Allow production to continue when a safety device fails

C. Allow a qualified maintenance technician to temporarily defeat a safety interlock in a controlled manner (following specific procedures, with appropriate safeguards, during maintenance or troubleshooting only) — never for production operation

D. Reset tripped safety devices without investigating the cause

96. When a stationary engineer discovers a natural gas odor in a mechanical equipment room, the correct immediate response is to?

A. Evacuate all personnel immediately, do not operate any electrical switches or create any ignition sources, ventilate if possible by opening doors and windows, call the gas utility and fire department from outside the building, and do not re-enter until declared safe

B. Open a window and continue investigating the source

C. Turn on the room ventilation fan to dilute the gas concentration

D. Use a combustible gas detector to locate the leak before calling anyone

97. The purpose of personal fall arrest equipment (harness and lanyard) in electrical construction work is to?

A. Allow workers to climb ladders faster and more safely

B. Support the worker's weight during extended elevated work periods

C. Connect the worker to the structural support above the work area only

D. Arrest a fall before the worker contacts a lower level — the system must be rigged so the maximum free fall does not exceed 6 feet and the total arrest distance does not result in contact with a lower level or obstruction

97. Personal fall arrest systems must be inspected?

A. Before each use by the worker — checking for cuts, abrasions, chemical damage, broken stitching, deformed hardware, and missing or illegible labels; any defective equipment must be immediately removed from service and tagged out

B. Monthly by a competent person only

C. Annually by the manufacturer's representative

D. Only after a fall has been arrested — routine inspection is not required

98. The OSHA requirement for medical evaluation before an employee is fit-tested and uses a tight-fitting respirator is?

A. An annual pulmonary function test (spirometry)

B. A chest X-ray every two years

C. Physician evaluation of OSHA's mandatory medical questionnaire (29 CFR 1910.134 Appendix C) — the physician determines if the employee is medically able to use the assigned respirator

D. Completion of OSHA's mandatory medical questionnaire (29 CFR 1910.134 Appendix C) evaluated by a PLHCP (physician or licensed healthcare professional) — required before initial fit testing and when conditions change that may affect respirator use

99. The purpose of NFPA 70E's "energized electrical work permit" is to?

A. Replace the LOTO procedure for low-voltage circuits below 50V

B. Document the justification for performing energized work, identify the specific tasks, specify the required PPE and safety measures, and obtain written authorization from responsible management — creating a formal decision-making process that encourages de-energizing as the preferred option

C. Satisfy the NEC inspection requirement for electrical maintenance work

D. Authorize electrical workers to exceed OSHA's minimum safe work distances

100. The single most effective measure for preventing fatalities from electrical arc flash is?

A. Providing arc-rated PPE with the highest available arc rating for all electrical tasks

B. Installing arc flash warning labels on all electrical equipment per NEC 110.16

C. Training all electrical workers to recognize arc flash hazards in the workplace

D. Establishing and enforcing a culture and procedure where electrical equipment is de-energized and placed in an electrically safe work condition before work begins — PPE protects when energized work cannot be avoided, but elimination of the hazard through de-energizing is always the preferred and most effective control

PRACTICE EXAM 13 — ANSWER KEY AND FULL EXPLANATIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. Correct Answer: D — 20A - I = P ÷ V = 4,800 ÷ 240 = 20A. This is a direct application of the power formula for resistive circuits where current equals power divided by voltage.

2. Correct Answer: B — 0.04 seconds - Time constant $\tau = L \div R = 2 \div 50 = 0.04$ seconds. After one time constant, current reaches 63.2% of its final steady-state value in a series RL circuit.

3. Correct Answer: A — 1.8 joules - Energy stored in a capacitor: $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 40 \times 10^{-6} \times 300^2 = 1.8$ joules. This energy is stored in the electric field between the capacitor plates and released upon discharge.

4. Correct Answer: A — Thumb = motion, index finger = field, middle finger = current - Fleming's Left-Hand Rule applies to motors, with the three mutually perpendicular fingers representing force (motion), magnetic field, and current respectively. The Right-Hand Rule applies to generators producing EMF from conductor motion.

5. Correct Answer: D — 277V at −120° - In a balanced three-phase wye system with Phase A at 0°, Phase B lags by 120° (−120°) and Phase C lags by 240° in the standard A-B-C positive sequence rotation. The magnitude of all three phases remains equal at 277V.

6. Correct Answer: D — 25A - Transformer current ratio is the inverse of the turns ratio: I_secondary = 5 × (400 ÷ 80) = 25A. A step-down transformer steps voltage down and steps current up by the same turns ratio.

7. Correct Answer: C — 10Ω - Net reactance $X = XL - XC = 15 - 9 = 6\Omega$; impedance $Z = \sqrt{(R^2 + X^2)} = \sqrt{(64 + 36)} = \sqrt{100} = 10\Omega$. The circuit is net inductive since XL exceeds XC.

8. Correct Answer: A — V_RMS = V_peak ÷ √2 - The RMS value of a sinusoidal voltage equals 70.7% of the peak value. For a 120V RMS supply, the actual peak voltage is $120 \times \sqrt{2} = 169.7$V.

9. Correct Answer: D — Clamp voltage transients by conducting heavily when voltage exceeds the clamping voltage - An MOV has nonlinear resistance that drops dramatically above its clamping voltage, diverting surge current away from protected components. MOVs are the primary protection element in surge protective devices (SPDs) at service panels and sensitive equipment.

10. Correct Answer: A — Total power = 12 kW; PF = 0.866 - Total power = W1 + W2 = 8 + 4 = 12 kW. Power factor angle $\theta = \arctan(\sqrt{3} \times (8-4)/(8+4)) = \arctan(0.577) = 30°$; $PF = \cos(30°) = 0.866$ lagging.

11. Correct Answer: B — The nonlinear magnetizing inductance resonates with system capacitance producing dangerous overvoltages - Ferroresonance occurs when transformer magnetizing inductance resonates with cable or capacitor bank capacitance at or near system frequency, producing sustained overvoltages of several times normal. It is commonly triggered by single-phase switching of an unloaded transformer connected to a long cable run.

12. Correct Answer: B — Over-excited — supplying reactive power to the system - An over-excited synchronous motor draws leading current from the system, supplying reactive power like a capacitor bank. This property makes synchronous motors valuable for power factor correction in industrial facilities with large inductive loads.

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

13. Correct Answer: A — Ground fault circuit interrupters (GFCIs) - NEC 210.8(A) and (B) require GFCI protection for 15A and 20A, 125V receptacles in all listed wet or hazardous locations including bathrooms, garages, outdoors, crawl spaces, unfinished basements, and kitchens. AFCIs are required separately for dwelling unit branch circuits but do not replace the GFCI requirement.

14. Correct Answer: A — Three - NEC 310.15(C) requires ampacity derating when more than three current-carrying conductors occupy a single raceway. With 4–6 conductors the derating factor is 80%; 7–9 conductors requires 70%, per NEC Table 310.15(C)(1).

15. Correct Answer: B — MC cable with a moisture- and corrosion-resistant outer jacket listed for wet locations - Standard MC cable is not rated for wet locations. NEC 330.10(A)(11) requires MC cable in wet locations to have a corrosion-resistant jacket listed for that application, such as MC-PVC jacketed cable.

16. Correct Answer: A — In front of the equipment from floor to 6.5 feet and to the width of the equipment or 30 inches, whichever is greater - NEC 110.26(A) defines dedicated working space dimensions to ensure a safe, unobstructed area for operation and maintenance. This space must remain permanently clear — it cannot be used for storage or penetrated by piping or ducts.

17. Correct Answer: B — Virtually all dwelling unit branch circuits per NEC 2020 210.12 - The 2020 NEC expanded AFCI requirements to include all 120V, 15A and 20A branch circuits in dwelling units. AFCIs detect the unique current signatures of arcing faults — a leading cause of residential electrical fires — and open the circuit before ignition occurs.

18. Correct Answer: C — Evaluated by a nationally recognized testing laboratory (NRTL) and found to comply with applicable product safety standards - NEC Article 100 defines "listed" as equipment included in a list published by an NRTL such as UL, ETL, or CSA. Listing verifies the device has been tested and meets applicable construction and performance standards.

19. Correct Answer: B — Motors have high starting inrush current that would trip a device sized for conductor ampacity - NEC 430.52 permits motor branch circuit protection to be sized up to 250% of

FLA for inverse time breakers to allow motor starting. The overload relay sized at 115–125% FLA provides conductor protection during running conditions.

20. Correct Answer: D — Flexible cords are not permitted as a wiring method for permanent installations - NEC 400.7 lists the permitted uses of flexible cords and 400.8 lists prohibited uses — including as a substitute for fixed wiring or run through walls and ceilings. Cords are intended for portability and connection flexibility, not permanent installation.

21. Correct Answer: D — 0.58 - NEC Table 310.15(B)(1) correction factors reduce conductor ampacity at elevated ambient temperatures. For 75°C-rated conductors at 60°C ambient, the published NEC correction factor is 0.58 — reflecting the significantly reduced thermal headroom available for current-generated heat.

22. Correct Answer: B — Working on electrical equipment safely and recognizing the hazards involved - OSHA 1910.399 defines a qualified person based on demonstrated ability and knowledge specific to the work and voltage level — not solely on credentials or years of experience. Qualification is task-specific: a person qualified for 480V work may not be qualified for 15kV switchgear without additional training.

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

23. Correct Answer: B — Protect secondary conductors from the transformer's available fault current - A transformer can deliver very high fault current on its secondary, often far exceeding the downstream conductor's withstand rating. Tap fuses placed at the transformer secondary terminals protect these conductors when the upstream primary protection cannot clear secondary faults quickly enough.

24. Correct Answer: A — Primary disconnect → primary fuses/breaker → transformer → secondary main breaker → distribution section - This is the standard unit substation arrangement progressing from the utility interface through the transformer to load distribution. The primary disconnect allows safe transformer isolation; the secondary main breaker provides overall secondary protection.

25. Correct Answer: C — Continuously monitor the continuity of the equipment grounding conductor - Mining cables are subject to physical damage that can sever the ground conductor. A ground check monitor applies a low-level test signal through the ground conductor — if continuity is lost, the monitor trips the supply circuit immediately, preventing electrocution from a frame fault on ungrounded equipment.

26. Correct Answer: B — The breaker can safely interrupt a fault current up to 40 kA RMS symmetrical - The interrupting rating is the maximum fault current the breaker can safely interrupt without failure. If available fault current exceeds the interrupting rating, the breaker can fail catastrophically — all breakers must be installed where available fault current does not exceed their interrupting rating.

27. Correct Answer: B — Support bus voltage, reduce reactive current in lines, improve power factor, and increase real power transfer capacity - Reactive power compensation supplies local VAR

demand, reducing reactive current flow through transmission lines and transformers. This lowers I^2R losses, reduces voltage drop, and improves voltage stability — particularly critical during heavy load conditions.

28. Correct Answer: D — Has only one winding common to both input and output — no galvanic isolation - An autotransformer uses a single tapped winding where part of the winding carries both primary and secondary current simultaneously. While more efficient and compact than a two-winding transformer, it provides no electrical isolation between primary and secondary circuits.

29. Correct Answer: C — Any single element can be taken out of service without interrupting any circuit - In a ring bus, each circuit connects between two breakers in a closed ring. Opening any one breaker splits the ring into two sections while all circuits remain energized from both sides — providing high reliability with fewer breakers than a breaker-and-a-half scheme.

30. Correct Answer: C — Reduce available fault current at downstream buses - A series reactor adds inductive reactance in the fault current path, increasing total circuit impedance during faults and limiting the peak fault current. This reduces the interrupting duty on downstream breakers and mechanical stress on busbars, allowing use of lower-rated equipment downstream.

31. Correct Answer: B — The device nearest the fault operates first, clearing it with minimum service interruption - Protective device coordination ensures only the faulted circuit is interrupted — not the entire upstream feeder. This is achieved by ensuring downstream device time-current curves lie below upstream device curves at all fault current levels with a minimum coordination time interval (CTI) of 0.2–0.4 seconds.

32. Correct Answer: D — Limit ground fault current from the transformer to protect the core and windings - A transformer NGR limits the single-line-to-ground fault current to a safe value — typically 100–400A. Without it, a phase-to-ground fault could produce full three-phase fault current levels, causing severe core burning, winding damage, and structural damage from electromagnetic forces.

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

33. Correct Answer: B — Percentage change in terminal voltage from no-load to full-load at constant speed and field current - Voltage regulation $VR\% = (V_{NL} - V_{FL}) \div V_{FL} \times 100\%$. Lower VR% indicates better voltage regulation — synchronous generators typically have VR% of 20–40% due to their synchronous reactance causing voltage drop under load.

34. Correct Answer: C — Indicates the permissible overload multiplier above nameplate HP - A service factor of 1.15 means the motor can operate continuously at 115% of nameplate HP under rated voltage, frequency, and ambient temperature without exceeding its thermal rating. NEC permits overload relay sizing at 125% of FLA for motors with $SF \geq 1.15$.

35. Correct Answer: A — Rotating stator magnetic field interacting with currents induced in the rotor conductors - The stator's rotating magnetic field induces currents in the short-circuited rotor

conductors by transformer action. The interaction between these rotor currents and the stator field produces force (F = BIL) on each rotor conductor, creating the torque that drives the load.

36. Correct Answer: D — Defines the motor's physical mounting dimensions - NEMA frame numbers specify shaft height, shaft diameter and length, bolt hole locations, and overall frame dimensions. This standardization ensures motors from different manufacturers with the same frame number are dimensionally interchangeable — critical for replacement without modifying mounts or couplings.

37. Correct Answer: B — Gradually increases voltage using back-to-back SCRs to reduce starting current - A soft starter uses pairs of back-to-back SCRs to control firing angle, progressively increasing RMS voltage from a low initial value to full voltage over a programmable ramp time. Reduced voltage reduces starting current proportional to the square of the voltage ratio.

38. Correct Answer: B — 142.6A - Overload relay trip current = 124A × 1.15 = 142.6A. NEC 430.32(A)(1) permits overload protection set at up to 115% of FLA for motors with a temperature rise greater than 40°C or service factor less than 1.15.

39. Correct Answer: D — 554A - Phase-to-neutral voltage = 480 ÷ √3 = 277V. Fault current = 277V ÷ 0.5Ω = 554A. The fault current is limited only by the phase conductor impedance since the fault is bolted phase-to-neutral with no other impedance in the path.

40. Correct Answer: C — Uses a maintained-contact device allowing automatic restart after power interruption - Two-wire control uses a maintained contact device (thermostat, float switch, pressure switch) that holds the contactor closed automatically when its setpoint is satisfied. Unlike three-wire control, it allows automatic restart after a power interruption — which is preferred for process applications but undesirable where unexpected restart creates a safety hazard.

41. Correct Answer: A — Detune the capacitor bank from system harmonic frequencies - Series reactors shift the capacitor bank's resonant frequency away from dominant harmonic frequencies (5th, 7th). Without detuning reactors, the capacitor's low impedance at harmonic frequencies can create parallel resonance with transformer inductance, dramatically amplifying harmonic voltages throughout the system.

42. Correct Answer: D — The motor's locked rotor kVA per horsepower code letter - NEMA locked rotor code letters (NEC Table 430.7(B)) indicate the motor's starting kVA per horsepower. Code G = 5.6–6.3 kVA/HP, used to select the branch circuit overcurrent protective device — higher code letters require larger fuses or breakers to permit starting without nuisance tripping.

43. Correct Answer: C — Maintain continuous contact between the stationary circuit and rotating armature — reversing connections at the neutral axis to maintain unidirectional torque - The commutator acts as a mechanical rotary switch that reverses the external circuit connections to each armature coil as it passes through the magnetic neutral axis. This ensures the torque produced by each coil always acts in the same rotational direction, producing continuous unidirectional rotation.

44. Correct Answer: A — Return kinetic energy of the decelerating motor back to the AC supply as real power - An active front end (AFE) rectifier can operate in both rectifying and inverting modes — during motor deceleration, regenerated energy is inverted back to the AC supply rather than wasted as heat in a braking resistor. This significantly improves energy efficiency in applications with frequent deceleration cycles such as elevators, cranes, and centrifuges.

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

45. Correct Answer: A — Compare 30-second to 1-minute insulation resistance readings - DAR = $IR_{30s} \div IR_{1min}$. A ratio below 1.25 indicates wet, contaminated, or deteriorated insulation that cannot properly polarize. Good, dry insulation continues to rise in resistance over time, producing a DAR above 1.4.

46. Correct Answer: C — Transmission line reflection effects from IGBT switching speed - When IGBTs switch at high dV/dt rates, voltage waves travel down the motor cable and reflect at the motor terminals due to impedance mismatch — potentially doubling peak voltage. Long cables above 50–100 feet worsen the effect; output reactors or dV/dt filters are used to mitigate it.

47. Correct Answer: D — Verify low contact resistance to prevent overheating under load current - Circuit breaker contacts should measure below 50–200 μΩ depending on breaker current rating per NETA MTS acceptance criteria. High contact resistance from erosion, oxidation, or misalignment causes I^2R heating that leads to thermal failure and potential fire under sustained load.

48. Correct Answer: A — High-energy internal arcing fault - Acetylene (C_2H_2) is only generated when transformer oil is subjected to temperatures above 700°C — conditions occurring only during high-energy electrical arcing. Its presence in DGA results is a critical fault indicator requiring immediate investigation and often removal from service.

49. Correct Answer: A — Acceptable insulation — 50 MΩ well exceeds IEEE 43 minimums - IEEE 43-2013 recommends a minimum insulation resistance of 1 MΩ for motors rated up to 1 kV. A 50 MΩ reading at 500V DC after 1 minute indicates good insulation condition — the 500V test voltage is appropriate for 480V motors per IEEE 43.

50. Correct Answer: D — Determine relay settings ensuring the nearest device operates first while upstream devices serve as backup - Coordination study output is a set of time-current characteristic curves plotted on log-log paper. Proper coordination ensures each downstream curve lies entirely below the upstream curve at all fault current levels with a minimum CTI of 0.2–0.4 seconds between adjacent devices.

51. Correct Answer: C — 4.4% - Average current = (45+43+47) ÷ 3 = 45A. Maximum deviation = 47 − 45 = 2A. NEMA unbalance % = (2 ÷ 45) × 100 = 4.4%. NEMA MG1 recommends derating the motor when current unbalance exceeds 5% and requires investigation of the supply voltage.

52. Correct Answer: A — Assess harmonic impact, identify resonances, and design mitigation measures - A power system harmonic study models the system's frequency response to determine resonant

frequencies and harmonic voltage/current levels at each bus. It identifies transformer K-factor requirements, neutral conductor overloading risk, and designs passive or active harmonic filters to comply with IEEE 519 limits.

53. Correct Answer: D — Verify ground fault relay operates correctly and trips the appropriate breaker - Ground fault protection testing uses a primary injection test set to simulate a ground fault current at the sensor level. The test confirms the relay detects the fault at the correct sensitivity, trips within the specified time, and correctly operates the intended breaker — verifying the complete protection chain.

54. Correct Answer: D — Measure dielectric losses indicating contamination, moisture, or aging of insulation - Insulation power factor (tan δ) measures the ratio of resistive loss current to capacitive charging current. Clean, dry insulation has tan δ below 0.5%; values above 1–2% indicate moisture ingress, oil oxidation, or solid insulation degradation that accelerates electrical breakdown if not addressed.

MECHANICAL EQUIPMENT (Questions 55–63)

55. Correct Answer: D — Minimize internal recirculation from discharge back to suction - Wear rings create a close-clearance labyrinth seal between the impeller's high-pressure discharge side and the low-pressure suction eye. As they wear, internal recirculation increases, reducing pump efficiency — replaceable wear rings restore clearances without requiring replacement of expensive impellers or casings.

56. Correct Answer: D — Ratio of compressor discharge pressure to compressor inlet pressure - Compression ratio directly determines gas turbine thermal efficiency — higher ratios approach the ideal Brayton cycle efficiency. Modern industrial gas turbines achieve compression ratios of 15:1 to 35:1, limited by compressor surge margin and turbine inlet temperature constraints.

57. Correct Answer: C — Detect surge approach and open a recycle valve to maintain flow above minimum stable flow - Surge in a centrifugal compressor causes violent flow reversal, pressure oscillations, and potentially destructive mechanical loading on impellers and bearings. Anti-surge control maintains a minimum flow margin — typically 10% above the surge line — by recycling gas from discharge back to suction.

58. Correct Answer: A — Maintain constant boiler drum water level by matching feedwater flow to steam flow - Low water exposes heating surfaces causing overheating and tube failure; high water causes carryover of water droplets into steam lines, damaging turbine blades and causing water hammer. A three-element control (drum level, steam flow, feedwater flow) provides the most stable control across all load conditions.

59. Correct Answer: B — Remove heat from bearing friction and maintain oil within the specified temperature range - Bearing oil temperature should be maintained between 130–160°F (55–70°C) for proper viscosity and film thickness. Above this range, oil viscosity drops below the minimum needed for hydrodynamic lubrication, increasing metal-to-metal contact and accelerating bearing wear.

60. Correct Answer: D — Cool partially compressed air between stages to reduce compression work and thermal stress - Intercooling between compressor stages reduces inlet temperature to the next stage, allowing compression to approach isothermal rather than adiabatic — reducing total work of compression. It also removes condensate and protects high-pressure cylinder components from excessive thermal stress.

61. Correct Answer: A — Prevent machinery vibration from transmitting to the building structure - Vibration isolators provide a compliant interface between equipment and the supporting structure, attenuating vibration transmission. Proper isolation requires the isolator's natural frequency to be well below the equipment's operating frequency — typically one-third or less of the disturbing frequency.

62. Correct Answer: C — Ratio of dissolved solids concentration in recirculating water to makeup water - Cycles of concentration (CoC) = TDS_recirculating ÷ TDS_makeup. Higher CoC conserves water but increases scaling and corrosion risk. Most cooling tower water treatment programs target 3–6 cycles, balancing water conservation against water quality limits for the specific water chemistry.

63. Correct Answer: C — Energy waste from loss of live steam passing directly to the condensate return - A failed-open steam trap continuously passes live steam, wasting fuel and overloading the condensate return system. Steam trap surveys using ultrasonic, infrared, or visual inspection methods identify failed-open traps that can represent significant energy losses in large steam distribution systems.

FLUID SYSTEMS (Questions 64–72)

64. Correct Answer: A — Controls the volume of supply air to the zone by modulating a damper - VAV systems vary airflow to each zone in response to thermostat demand rather than varying air temperature. At part load, supply fan speed reduces proportionally — fan energy varies as the cube of speed, producing dramatic energy savings compared to constant volume systems.

65. Correct Answer: B — Opens and discharges water if temperature exceeds 210°F or pressure exceeds the rated setting - A T&P relief valve is the final safety device preventing a water heater from becoming a steam explosion hazard. If the thermostat fails and heating continues, the T&P valve opens before pressure or temperature reaches destructive levels — an improperly functioning or removed T&P valve creates an extreme explosion hazard.

66. Correct Answer: B — Outdoor wet-bulb temperature is low enough that cooling tower water can satisfy the cooling load - Waterside economizer uses cooling tower water to cool chilled water when outdoor wet-bulb temperature is sufficiently low, eliminating chiller compressor operation. This reduces cooling plant energy consumption by 70–90% during economizer hours, typically in fall, winter, and spring.

67. Correct Answer: B — Varies total system flow as it modulates — enabling variable flow and reduced pump energy - A two-way valve is essentially a variable restriction — as it closes, flow through that branch decreases, reducing total system flow when combined with a variable speed pump. Three-way valves maintain constant flow by diverting water between the coil and a bypass, preventing pump energy savings at part load.

68. Correct Answer: B — Remove particulates that would damage valve seat and plug - Control valve trim has very close tolerances — particulates in the flow stream cause erosive wear that progressively worsens shutoff capability. A properly sized Y-type or basket strainer with mesh appropriate for the valve trim protects the valve and significantly extends its service life.

69. Correct Answer: D — Steam temperature above its saturation temperature at a given pressure - Superheated steam has been heated beyond saturation temperature — it behaves more like an ideal gas, resists condensation during transmission, and contains more energy per pound than saturated steam. Superheat also eliminates moisture droplets that would erode turbine blading.

70. Correct Answer: B — Discharge recirculating water to prevent dissolved solids buildup - As cooling tower water evaporates, dissolved minerals and treatment chemicals concentrate. Blowdown removes a controlled portion of concentrated water, which is replaced by fresh makeup water — maintaining the cycles of concentration within acceptable limits for scale and corrosion control.

71. Correct Answer: A — 3–15 PSI - The 3–15 PSI pneumatic signal range is the global standard for pneumatic control instruments. 3 PSI represents 0% output (valve fully closed) and 15 PSI represents 100% output (valve fully open), providing sufficient force to overcome actuator spring forces while remaining safe for standard components.

72. Correct Answer: D — Minimum temperature difference between hot fluid outlet and cold fluid inlet - Approach temperature is a key heat exchanger performance indicator — a smaller approach temperature indicates more effective heat transfer but requires more surface area (larger, more expensive exchanger). In a counterflow heat exchanger, the approach temperature occurs at the end where the hot fluid exits and the cold fluid enters.

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

73. Correct Answer: A — Provide a low-resistance fault current path to trip the overcurrent device during insulation failure - The EGC in a portable tool's cord connects the metal housing to the grounding pin of the plug. A ground fault energizes the housing and fault current flows through the EGC to trip the branch circuit breaker — clearing the fault before a user contacting the tool frame receives a dangerous shock.

74. Correct Answer: D — 6 strands with 37 wires each — more wires per strand provides flexibility but less abrasion resistance - Wire rope construction notation is strands × wires per strand. 6×37 rope has many small wires making it very flexible (suitable for crane hoisting lines with frequent bending over sheaves) but susceptible to abrasion. 6×7 rope has fewer, larger wires — stiffer but more abrasion resistant, suitable for static applications like guy wires.

75. Correct Answer: D — Prevent passage of gases, vapors, or flames through conduit between hazardous and non-hazardous areas - NEC 501.15 requires conduit seals in Class I hazardous locations within 18 inches of explosion-proof enclosures and at boundaries between hazardous and non-hazardous

areas. The cured sealing compound creates an impenetrable barrier preventing flammable gas migration through the conduit to ignition sources.

76. Correct Answer: C — Maximum load rated for normal rigging practice — breaking strength divided by a design factor - The WLL is determined by dividing the minimum breaking force (MBF) by a design factor of 4:1 to 5:1 per ASME B30.9 and B30.26. The WLL is marked on all rigging hardware and must never be exceeded — sling angle reductions further reduce the effective WLL of sling assemblies.

77. Correct Answer: A — Achieve specified contact pressure for low-resistance connections without overstressing hardware or insulators - Manufacturer torque specifications for bus bar connections are determined by testing to find the optimal clamping force. Undertorquing causes high-resistance connections and overheating; overtorquing cracks insulators, yields bus bar material, or strips fastener threads.

78. Correct Answer: B — Grip round pipe surfaces by self-tightening under load - The pipe wrench's floating upper jaw pivots slightly under applied force, increasing grip as more torque is applied — preventing slippage on smooth cylindrical surfaces. This self-energizing action works in the tightening direction only; the jaw releases easily in the opposite direction for repositioning.

79. Correct Answer: A — Check all components before each use and remove defective equipment from service - OSHA 1910.140 and ANSI Z359 require pre-use inspection of all personal fall arrest equipment before each use, checking for physical damage, chemical degradation, deformed hardware, and missing labels. Any equipment that has arrested a fall must be immediately removed from service pending inspection by a competent person.

80. Correct Answer: C — Verified for level accuracy against a known reference before use - Laser levels can be knocked out of calibration by job site impacts or shipping. Before use for critical conduit alignment, verify accuracy by shooting to a target, marking the point, rotating 180°, and checking if the beam returns to the same mark — any discrepancy requires recalibration before proceeding.

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. Correct Answer: C — Maintain SDSs for each hazardous chemical, label containers, and train employees - OSHA HazCom 2012 (29 CFR 1910.1200) requires a written hazard communication program, GHS-compliant SDSs readily accessible to employees, proper container labeling, and employee training on chemical hazards and protective measures. These requirements apply to any chemical presenting a physical or health hazard.

82. Correct Answer: B — Identify hazards at each job step and specify controls before work begins - A JSA/JHA systematically breaks a task into sequential steps, identifies the specific hazard at each step, and documents engineering controls, administrative controls, and PPE needed to address each hazard. Worker involvement in JSA development is critical because workers performing the task have the most practical knowledge of real hazards.

83. Correct Answer: A — A Site Safety Training (SST) card requiring 40 hours of OSHA-approved training - NYC Local Law 196 requires most workers on covered construction sites to carry an SST card — 40 hours of approved training for workers and 62 hours for supervisory personnel. The card must be on the worker's person at all times on the site; non-compliance results in removal from the site and civil penalties.

84. Correct Answer: D — Listed highly hazardous chemical present in a process at or above its threshold quantity - OSHA PSM (1910.119) covers processes containing listed highly hazardous chemicals at or above the threshold quantities in Appendix A. PSM requires a comprehensive program including process hazard analysis (PHA), written operating procedures, mechanical integrity program, management of change, and incident investigation.

85. Correct Answer: C — Lung cancer, nasal septum damage, and sensitization dermatitis - Hexavalent chromium (Cr VI) is a confirmed human carcinogen (IARC Group 1) primarily causing lung cancer from inhalation. It also causes nasal septum perforation, skin ulcers, and allergic contact dermatitis — OSHA's PEL is 5 µg/m³ and action level is 2.5 µg/m³ as an 8-hour TWA per 29 CFR 1910.1026.

86. Correct Answer: D — Facilities storing petroleum above threshold quantities with potential to reach navigable waters - EPA's SPCC rule (40 CFR Part 112) applies to facilities with total aboveground petroleum storage above 1,320 gallons where a discharge could reasonably reach navigable waters. SPCC plans must include secondary containment, inspection programs, and spill response procedures.

87. Correct Answer: B — Provide occupational exposure limits, required engineering controls, and recommended PPE - SDS Section 8 is the primary reference for workplace exposure control — listing OSHA PELs, ACGIH TLVs, and NIOSH RELs; specifying required ventilation and engineering controls; and recommending specific PPE including glove type, respirator type and cartridge specification, and eye protection for the chemical's hazard profile.

88. Correct Answer: B — Pretreatment standards before discharge to the municipal sewer (POTW) - EPA's Industrial Pretreatment Program (40 CFR Part 403) requires industrial users discharging to a POTW to remove pollutants that would interfere with biological treatment, pass through to the receiving water body, or contaminate biosolids. Categorical pretreatment standards apply to specific industries; local limits are set by the individual POTW.

89. Correct Answer: C — Provide emergency planners and fire departments with hazardous chemical inventory information - EPCRA Section 312 Tier II reports (due March 1 annually) require facilities to report chemicals stored above threshold quantities to the SERC, LEPC, and local fire department. This information enables emergency responders to pre-plan chemical release responses — knowing what chemicals are present, in what quantities, and where they are stored.

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

90. Correct Answer: C — Elimination → Substitution → Engineering controls → Administrative controls → PPE - This hierarchy prioritizes controls that permanently remove hazards over those that

rely on human behavior. Elimination (de-energizing) is always preferred over PPE, which is the least reliable control because it depends entirely on correct selection, use, and maintenance by the worker.

91. Correct Answer: A — Specific shutdown steps, location and type of each energy isolating device, energy source types and magnitudes, and verification method - OSHA 1910.147(c)(4) requires equipment-specific LOTO procedures for equipment with multiple energy sources or complex isolation requirements. The written procedure ensures any authorized employee can safely isolate the equipment without relying on memory or undocumented institutional knowledge.

92. Correct Answer: D — Authorize entry, verify conditions, oversee the permit system, and cancel the permit when conditions change - OSHA 1910.146 defines the entry supervisor as the person responsible for determining if acceptable entry conditions are present, authorizing entry, overseeing entry operations, and terminating entry when required. The entry supervisor may also serve as an attendant or authorized entrant if properly trained for all roles.

93. Correct Answer: C — Rubber insulating gloves rated for the voltage, safety glasses or face shield, and arc-rated PPE - NFPA 70E requires both shock protection (rubber insulating gloves rated for the voltage class) and arc flash protection (arc-rated PPE matched to the incident energy or PPE category) for energized electrical work. Testing at an energized MCC constitutes electrical work — PPE for both hazards is mandatory.

94. Correct Answer: B — Testing all system components per NFPA 72 Table 14.4.5 required frequencies - NFPA 72 requires comprehensive annual testing of all fire alarm system components including detectors, manual pull stations, notification appliances, control panels, batteries, and supervisory devices. Some components may use statistical sampling schedules, but overall system functionality must be verified annually.

95. Correct Answer: C — Allow qualified maintenance technicians to temporarily defeat a safety interlock in a controlled manner during maintenance only - Safety interlock bypasses are legitimate maintenance tools when used with documented procedures, supervisor authorization, and alternative safeguards in place. Using bypass switches to keep equipment running during production defeats their safety purpose entirely and creates serious OSHA liability.

96. Correct Answer: A — Evacuate, avoid ignition sources, ventilate from outside, and call gas utility and fire department from outside - Natural gas ignites at 5–15% concentration in air, and any electrical switch can create a spark sufficient to ignite an explosive atmosphere. Evacuation must happen before any switches are operated — ventilation fans inside the space must never be activated as they can create an ignition source.

97. Correct Answer: A — Before each use by the worker, checking for all forms of physical damage - OSHA 1910.140(c)(19) requires pre-use inspection of all personal fall arrest equipment by the user before each use. Equipment that has arrested a fall must be immediately removed from service — even if it appears undamaged, internal energy-absorbing components may be compromised and unable to arrest a subsequent fall.

98. Correct Answer: D — Completion of OSHA's mandatory medical questionnaire evaluated by a PLHCP before initial fit testing - OSHA 1910.134(e) requires employers to provide a medical evaluation using OSHA's mandatory questionnaire (Appendix C) before any employee is fit-tested or required to use a respirator. The PLHCP reviews the questionnaire and determines medical fitness — conditions such as heart or pulmonary disease may preclude certain respirator types.

99. Correct Answer: B — A designated primary authorized employee applies a group lockout hasp on each energy isolation point — each worker applies their personal lock to the hasp, and the primary authorized employee verifies all energy is controlled before work begins - OSHA 1910.147(f)(3) addresses group LOTO procedures. Each worker in the group applies their individual personal lock to the group hasp(s) — no work begins until all locks are applied and all energy sources are verified isolated. When a worker completes their portion of work, they remove only their own personal lock.

100. Correct Answer: D — De-energizing equipment before work begins — making energized work the rare, justified exception - All other controls — PPE, labels, training — provide layers of protection after the hazard has been accepted as unavoidable. De-energizing eliminates the arc flash and shock hazard entirely. NFPA 70E and OSHA both recognize that facilities with strong "de-energize first" cultures produce the lowest electrical injury and fatality rates.