PRACTICE EXAM 11: STATIONARY ENGINEER (ELECTRIC) SIMULATION — 100 QUESTIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. A 120V, 60W incandescent lamp operates for 8 hours. The energy consumed in kilowatt-hours is?

A. 480 kWh

B. 0.48 kWh

C. 4.8 kWh

D. 0.048 kWh

2. The term "power factor" in an AC circuit is the ratio of?

A. Apparent power to reactive power

B. Reactive power to real power

C. Real power to apparent power

D. Impedance to resistance

3. Which of the following describes the behavior of a purely capacitive circuit when AC voltage is applied?

A. Current and voltage are in phase

B. Current lags voltage by 90°

C. Current lags voltage by 45°

D. Current leads voltage by 90°

4. Kirchhoff's Current Law (KCL) states that?

A. The sum of all currents entering a node equals the sum of all currents leaving that node

B. The sum of all voltages around a closed loop equals the supply voltage

C. Current is always equal in all branches of a parallel circuit

D. The algebraic sum of all voltages in a series circuit equals zero

5. A 480V, three-phase, 4-wire wye system has a phase-to-neutral voltage of approximately?

A. 480V

B. 277V

C. 208V

D. 120V

6. Two capacitors of 10 μF and 20 μF are connected in series. The total capacitance is?

A. 30 μF

B. 6.67 μF

C. 15 μF

D. 200 μF

7. The unit of inductance is the?

A. Farad

B. Tesla

C. Henry

D. Weber

8. A 10Ω resistor, a 30Ω inductive reactance, and a 6Ω capacitive reactance are connected in series across 100V AC. The circuit current is approximately?

A. 10A

B. 5.3A

C. 2.5A

D. 4.08A

9. In a three-phase delta-connected load, the relationship between line current (IL) and phase current (Iph) is?

A. IL = Iph

B. IL = $\sqrt{3} \times$ Iph

C. IL = Iph $\div \sqrt{3}$

D. IL = $3 \times$ Iph

10. Lenz's Law states that?

A. The induced EMF in a conductor is proportional to the rate of change of current

B. The force on a conductor in a magnetic field is proportional to the current and field strength

C. The induced EMF opposes the change in flux that caused it

D. Magnetic flux is proportional to the number of turns and current in a coil

11. The dielectric strength of an insulating material refers to?

A. Its ability to store electrical charge

B. Its resistance to current flow at DC voltages

C. Its flexibility and mechanical strength under load

D. The maximum electric field strength it can withstand before electrical breakdown occurs

12. In an AC circuit, the true power consumed is calculated as?

A. $P = V \times I \times \cos(\theta)$, where θ is the phase angle between voltage and current

B. $P = V \times I$ only

C. $P = V^2 \div R$ only

D. $P = I^2 \times Z$, where Z is impedance

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

13. The NEC requires that service entrance conductors in a raceway be protected from physical damage. Which of the following is NOT an approved wiring method for service entrance conductors?

A. Rigid metal conduit (RMC)

B. Intermediate metal conduit (IMC)

C. Flexible metal conduit (FMC) as the primary raceway for service entrance conductors

D. Schedule 80 PVC conduit

14. Which conductor material requires anti-oxidant compound applied at terminations and splices?

A. Copper — to prevent galvanic corrosion

B. Aluminum — to prevent oxidation that increases contact resistance at connections

C. Tinned copper — to prevent tin whisker formation

D. Copper-clad aluminum — to prevent delamination

15. The NEC requires that panelboards supplying dwelling units be provided with a means to disconnect all ungrounded conductors. This means must be?

A. A single main breaker rated at least 200A

B. Not more than six switches or circuit breakers (the "six-handle rule") or a single main disconnect

C. A fused main disconnect rated at 125% of the calculated load

D. Two separate 100A main breakers for redundancy

16. A 15A, 120V branch circuit using 14 AWG copper conductors may supply continuous loads up to a maximum of?

A. 12A — continuous loads are limited to 80% of the branch circuit rating

B. 15A — the full rating applies to continuous loads

C. 10A — a 67% derating applies for continuous loads

D. 18A — continuous loads may use a 120% allowance

17. Which of the following describes a "qualified electrical worker" requirement for working on or near exposed energized conductors above 50V?

A. Completion of an OSHA 10-hour general industry card

B. Possession of a valid journeyman electrician license

C. Minimum of two years of electrical maintenance experience

D. Demonstrated knowledge of the hazards, ability to work safely, and training appropriate to the specific equipment and voltage level

18. The purpose of an equipment bonding jumper (EBJ) in an electrical installation is to?

A. Connect the neutral conductor to the panel enclosure at the service

B. Provide the grounding electrode connection at the service

C. Connect metal parts of the electrical equipment to ensure electrical continuity and the ability to safely conduct any fault current imposed on it

D. Connect multiple grounding electrodes together in the electrode system

19. NEC Article 500 classifies hazardous locations by Class, Division, and Group. Class I locations contain?

A. Ignitable fibers or flyings

B. Flammable gases or vapors in sufficient concentration to produce an ignitable mixture with air

C. Combustible dust in sufficient concentration to produce an ignitable mixture

D. Both flammable gases and combustible dusts simultaneously

20. A two-pole, 240V circuit breaker trips on one pole only. The most likely cause is?

A. An open neutral conductor in the circuit

B. An overloaded neutral conductor

C. A ground fault on the un-tripped pole

D. An overload or fault current on that pole's conductor only — the two poles share a common trip bar but each pole has its own thermal-magnetic element

21. The purpose of conduit expansion fittings installed in a long conduit run is to?

A. Increase the internal diameter of the conduit for easier wire pulling

B. Allow conductors to be spliced within the conduit

C. Compensate for thermal expansion and contraction of the conduit without stressing the conduit body, supports, or enclosure connections

D. Provide a weatherproof seal at building penetrations

22. A 30A, 240V, two-wire circuit (no neutral) uses 10 AWG copper THWN in conduit. The voltage drop at 100 feet (one-way) carrying 28A is approximately?

A. 3.5V

B. 8.9V

C. 11.2V

D. 4.4V

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

23. A utility protective relay scheme using "pilot relaying" differs from conventional distance or overcurrent relaying in that pilot relaying?

A. Uses current transformers only — no voltage transformers required

B. Provides time-delayed backup protection for remote bus faults

C. Requires manual operator intervention to trip the breaker

D. Uses a communication channel between line terminals to compare measured quantities at both ends, enabling high-speed simultaneous tripping of all terminals for any internal fault

24. The purpose of a power line carrier (PLC) system in a substation is to?

A. Transmit metering data from the substation to the utility billing system

B. Provide voice communication between substation operators

C. Supply control power to substation relays during utility outages

D. Use the high-voltage transmission line itself as a communication medium — transmitting protection signals, telemetry, and control commands between substations

25. In a resistance-grounded medium-voltage system (high-resistance grounded), the ground fault current is limited to?

A. Zero — no fault current flows in a resistance-grounded system

B. A few amperes (typically 1–10A) — sufficient to detect a fault but not enough to cause significant arc damage, allowing continued operation while the fault is located

C. 100–200A — sufficient to trip the feeder overcurrent device quickly

D. The full short circuit current of the system — the resistance only limits steady-state current

26. A power transformer's nameplate lists "OA/FA/FOA" cooling ratings of 50/67/84 MVA. This means?

A. The transformer has three separate cooling stages — OA (self-cooled) at 50 MVA, FA (forced air) at 67 MVA, and FOA (forced oil and air) at 84 MVA — each stage increasing capacity by activating additional cooling equipment

B. The transformer can be operated at any of these ratings continuously without any cooling systems

C. The three ratings represent summer, spring/fall, and winter capacities respectively

D. The transformer requires all cooling stages active to achieve 84 MVA output

27. The primary purpose of a load flow (power flow) study in power system planning is to?

A. Calculate the maximum short circuit current at each bus

B. Determine the optimal location for capacitor bank installations only

C. Assess transient stability following a fault event

D. Determine steady-state voltages, currents, real and reactive power flows, and equipment loading throughout the power system under normal and contingency conditions

28. A 34.5kV overhead transmission line uses ACSR (Aluminum Conductor Steel Reinforced) conductor. The steel core provides?

A. Improved electrical conductivity compared to solid aluminum

B. Reduced sag at high operating temperatures

C. Additional insulation between the conductor strands

D. Mechanical strength to support the conductor's weight and tension loads — the aluminum strands carry the electrical current while the steel core provides tensile strength

29. Which relay function (ANSI) protects a generator against motoring — absorbing real power from the system instead of generating it?

A. ANSI 40 — Loss of field relay

B. ANSI 51 — Time overcurrent relay

C. ANSI 32 — Directional power (anti-motoring) relay

D. ANSI 81 — Frequency relay

30. The purpose of a neutral grounding resistor (NGR) on a medium-voltage generator is to?

A. Improve generator power factor during light load operation

B. Limit the ground fault current from the generator to a safe level while allowing the protection system to detect and clear the fault

C. Provide a reference voltage for the generator's AVR (automatic voltage regulator)

D. Prevent ferroresonance on the generator bus during switching

31. A high-voltage DC (HVDC) transmission link is preferred over AC for very long distance power transmission primarily because?

A. DC transmission has no reactive power losses in the line, no skin effect, no charging current in cables, and no stability limits — allowing more power to be transmitted over a given conductor size for very long distances or long submarine cable crossings

B. DC transformers are more efficient than AC transformers

C. DC circuit breakers are less expensive than AC breakers at high voltages

D. DC lines require fewer conductors than AC lines at the same power level

32. In a protective relay scheme, "reach" refers to?

A. The relay's ability to detect faults through a transformer

B. The physical distance between the relay and the protected equipment

C. The impedance boundary within which the relay will operate — for a distance relay, the maximum impedance (proportional to line length) at which the relay will trip for a fault

D. The relay's operating time at maximum fault current

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

33. A brushless excitation system on a synchronous generator eliminates the need for slip rings and brushes by?

A. Using permanent magnets in the rotor to provide all excitation without any external DC source

B. Using solid-state switching to inject DC into the main field through the shaft

C. Mounting a small AC exciter on the same shaft — its AC output is rectified by rotating diodes on the rotor shaft and fed directly to the main field winding — no stationary brushes required

D. Using a separate DC motor-generator set to supply field current through a contactless coupling

34. The purpose of a motor's duty cycle rating is to?

A. Define the maximum voltage variation the motor can withstand

B. Establish the minimum insulation class required for the motor winding

C. Specify the maximum number of starts per hour for the motor

D. Define the pattern of load, no-load, and rest periods for which the motor is thermally designed — ensuring the motor does not overheat in its intended application

35. In a variable frequency drive, the DC bus voltage for a 480V input VFD is approximately?

A. 480V DC

B. 240V DC

C. 600V DC

D. 679V DC — the rectified and filtered peak of the 480V AC input ($480 \times \sqrt{2} = 679V$)

36. A motor's insulation class rating directly determines?

A. The motor's maximum ambient temperature for operation

B. The maximum allowable winding temperature rise above ambient — Class F allows 105°C rise, Class H allows 125°C rise

C. The motor's maximum operating voltage

D. The minimum required megger test voltage for the motor

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

A. Protect the VFD output transistors from overvoltage during starting

B. Provide additional torque during motor acceleration

C. Limit inrush current during VFD startup

D. Dissipate the regenerated energy from the motor as heat when the motor decelerates rapidly — preventing DC bus overvoltage that would trip the drive

38. An electric motor produces a shaft output of 25 HP at an efficiency of 92%. The input power drawn from the supply is approximately?

A. 20.3 kW

B. 18.6 kW

C. 25 kW

D. 22.5 kW

39. The purpose of a contactor's arc chutes is to?

A. Prevent contact bounce during closing

B. Protect the coil insulation from heat generated during switching

C. Reduce the contact closing speed to minimize mechanical wear

D. Extinguish the arc that forms between the contacts when they open under load — by stretching, cooling, and ultimately interrupting the arc

40. In a motor control circuit, a "seal-in" contact (also called a "holding" or "maintaining" contact) is used to?

A. Prevent the motor from running in reverse

B. Connect the motor to the emergency power source during utility outage

C. Disconnect the motor if the supply voltage drops below a set level

D. Maintain the contactor coil energized after the momentary start pushbutton is released — creating a self-latching circuit that holds the motor running until the stop button is pressed

41. The synchronous speed of a 4-pole, 60Hz induction motor is?

A. 1,800 RPM

B. 3,600 RPM

C. 900 RPM

D. 1,200 RPM

42. A motor protection relay detects negative sequence current and issues a trip. This most likely indicates?

A. Motor overload from excessive mechanical load

B. Ground fault between winding and frame

C. Motor locked rotor condition

D. Phase unbalance or phase loss in the supply — negative sequence current flows in all motors whenever the three supply voltages are not perfectly balanced

43. The purpose of a position encoder (resolver or encoder) on a servo motor is to?

A. Measure motor winding temperature for thermal protection

B. Provide precise shaft position and speed feedback to the servo drive controller — enabling accurate position and velocity control

C. Detect bearing wear through vibration sensing

D. Measure motor current for the drive's overcurrent protection

44. A 480V, 3-phase motor draws 42A FLA at rated load. The NEC minimum branch circuit conductor ampacity (before any derating) must be at least?

A. 52.5A — 125% of FLA per NEC 430.22

B. 42A — FLA only

C. 63A — 150% of FLA

D. 47A — 112% of FLA

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

45. When performing a megger test on a motor, the polarization index (PI) is calculated as?

A. The ratio of the 5-minute to 1-minute insulation resistance readings

B. The ratio of the 30-second to 15-second readings multiplied by 2

C. The ratio of the 10-minute insulation resistance reading to the 1-minute reading

D. The difference between the maximum and minimum readings during a 10-minute test

46. A power quality meter records a Total Harmonic Distortion (THD) of 18% on a 480V bus. This level indicates?

A. Significant harmonic distortion that may cause transformer overheating, neutral conductor overloading, nuisance tripping of breakers, and interference with sensitive electronic equipment — IEEE 519 recommends THD below 5% at the point of common coupling

B. Normal harmonic levels for an industrial facility — no action required

C. A critical fault requiring immediate shutdown of all VFDs and non-linear loads

D. Harmonic distortion within IEEE 519 limits for all facility types

47. A clamp-on power meter measures 42 kW real power and 28 kVAR reactive power on a feeder. The apparent power and power factor are?

A. 70 kVA at 0.60 PF

B. 14 kVA at 0.42 PF

C. 50.5 kVA at 0.83 PF

D. 42 kVA at 1.0 PF

48. The purpose of a partial discharge (PD) test on medium-voltage cable is to?

A. Verify the cable's DC insulation resistance

B. Determine the cable's charging current at operating frequency

C. Detect voids, delaminations, and contamination in cable insulation that generate partial discharges — an early indicator of insulation degradation before complete failure occurs

D. Measure the cable's capacitance per unit length for charging current calculation

49. When troubleshooting a three-phase motor that hums and fails to start, the most likely cause is?

A. Single-phasing — one of the three supply phases is missing, leaving the motor unable to develop starting torque while the remaining two phases draw locked rotor current through the windings

B. Motor overload relay tripped

C. Low supply voltage across all three phases

D. Incorrect motor rotation direction

50. The purpose of a transformer turns ratio (TTR) test is to?

A. Measure transformer insulation resistance

B. Verify correct transformer tap position

C. Verify the actual turns ratio of each winding matches the nameplate — detecting open circuits in a winding, shorted turns, or incorrect tap connections that would affect voltage regulation and protection relay settings

D. Measure transformer core losses at no load

51. A ground fault on a 480V ungrounded delta system will?

A. Immediately trip the system overcurrent protection — fault current is unlimited in an ungrounded system

B. Allow the system to continue operating with one phase grounded — until a second ground fault on a different phase creates a phase-to-phase fault through ground

C. Cause zero fault current — no current can flow without a ground return path

D. Trip the equipment ground fault protection relay immediately

52. Ultrasonic testing of electrical equipment detects?

A. Corona discharge, arcing, and partial discharge — all of which emit ultrasonic sound waves detectable with a handheld ultrasonic probe, even through equipment enclosures

B. Elevated conductor temperatures in bus bars and connections

C. Insulation resistance degradation in transformer windings

D. Mechanical bearing defects in motor rotors

53. The purpose of a protective relay's "time dial" or "time multiplier" setting is to?

A. Set the relay pickup current level

B. Select the relay's characteristic curve shape (inverse, very inverse, extremely inverse)

C. Establish the relay's operating voltage threshold

D. Scale the time-current characteristic curve up or down to achieve the desired coordination time interval between upstream and downstream protective devices

54. A battery room for a UPS system requires ventilation because?

A. Lead-acid batteries produce hydrogen gas during charging — hydrogen concentrations above 4% (LEL) in air are explosive

B. Battery charging produces excessive heat that must be exhausted to prevent room temperature from rising

C. The electrolyte fumes require dilution to below OSHA PEL levels

D. NEC requires forced ventilation in all electrical equipment rooms

MECHANICAL EQUIPMENT (Questions 55–63)

55. A centrifugal pump operating far to the right of its Best Efficiency Point (BEP) on the H-Q curve will experience?

A. Increased head and reduced flow — moving back toward BEP

B. Increased efficiency from higher flow velocity

C. High flow, reduced head, increased NPSH required, possible cavitation, and high radial bearing loads — operating continuously far right of BEP significantly reduces pump and bearing life

D. Stable operation with reduced power consumption

56. The purpose of a diesel engine's turbocharger is to?

A. Increase engine oil pressure for high-load lubrication

B. Reduce exhaust emissions by burning unburned fuel in the exhaust stream

C. Cool the engine coolant by using exhaust gas heat exchange

D. Compress the intake air charge above atmospheric pressure — increasing air density so more fuel can be burned per cycle, significantly increasing engine power output without increasing engine displacement

57. Which type of coupling is used when two shafts must transmit torque but cannot be perfectly aligned due to thermal expansion or installation limitations?

A. Rigid sleeve coupling — for maximum torque transmission

B. Flexible coupling (jaw, disc, or gear type) — accommodating angular, parallel, and axial misalignment while transmitting torque

C. Solid flange coupling — for high-speed applications

D. Compression coupling — for transmitting torque in both directions

58. In a reciprocating compressor, unloading is accomplished by?

A. Reducing motor speed to minimum RPM

B. Opening the compressor discharge valve to atmosphere

C. Bypassing compressed air back to the suction header

D. Holding the suction valve open during the compression stroke — preventing pressure buildup so the piston does no compression work, reducing power consumption when full capacity is not needed

59. The purpose of a mechanical seal's "flush" is to?

A. Cool and lubricate the seal faces by circulating clean fluid across them — preventing the faces from running dry, controlling seal face temperature, and removing contaminants from the sealing interface

B. Clean the pump casing of process residue during operation

C. Provide cooling water to the pump bearing housings

D. Flush the pump suction strainer during operation

60. A steam boiler's safety valve is required to be sized to?

A. Match the boiler's normal operating pressure only

B. Open at exactly the MAWP (Maximum Allowable Working Pressure) of the boiler

C. Provide 10% overpressure protection only

D. Relieve the maximum steam generating capacity of the boiler (in lbs/hr or BTU/hr) so that pressure cannot rise above the MAWP + allowable accumulation even with all other controls failed and maximum heat input applied

61. The purpose of an oil analysis program on rotating equipment is to?

A. Determine when to change the lubricant based on calendar schedule only

B. Measure the oil's viscosity at room temperature only for purchasing decisions

C. Verify that the oil meets the original specification before installation

D. Monitor lubricant condition (viscosity, oxidation, additive depletion) and contamination (water, particles, metals) to detect developing mechanical faults, optimize oil change intervals, and prevent premature failures

62. A reciprocating pump's pulsation dampener is installed to?

A. Protect the pump from water hammer during rapid valve closure

B. Balance pump flow between multiple discharge lines

C. Reduce pump noise by absorbing mechanical vibration from the crankshaft

D. Absorb the pressure pulsations produced by the intermittent discharge strokes — protecting downstream piping, instruments, and equipment from fatigue damage caused by cyclic pressure variations

63. When aligning a pump-motor direct drive coupling using a dial indicator method, the acceptable Total Indicator Reading (TIR) for a standard flexible coupling at 1,800 RPM is typically?

A. Up to 0.050" TIR — acceptable for all coupling types

B. Up to 0.020" TIR for angular misalignment only

C. Within 0.002"–0.005" TIR for both angular and parallel (offset) misalignment — tighter tolerances are required for higher speeds and precision couplings

D. Within 0.010"–0.015" TIR for parallel offset only

FLUID SYSTEMS (Questions 64–72)

64. Bernoulli's principle applied to a venturi meter states that as fluid velocity increases through the throat?

A. Both pressure and velocity increase proportionally

B. Static pressure decreases as kinetic energy increases — the pressure differential between the inlet and throat is used to calculate flow rate

C. The fluid temperature increases due to compression

D. Fluid density increases at the throat due to higher pressure

65. The purpose of a relief valve bypass line (around a pressure reducing valve) in a steam system is to?

A. Allow manual control of steam flow when the PRV is bypassed for maintenance or if the PRV fails — the bypass valve is manually throttled to maintain downstream pressure

B. Provide additional flow capacity beyond the PRV's rated capacity

C. Prevent the PRV from opening during normal operation

D. Automatically bypass the PRV when downstream pressure drops below setpoint

66. In a chilled water system, the "delta-T" across the chiller evaporator typically decreases (rises less than design) when?

A. Chilled water flow rate is higher than design — the water passes through the evaporator too quickly to pick up the full design heat load, resulting in a smaller temperature differential between supply and return

B. The chiller is operating at full load

C. Cooling load in the building increases above design

D. Condenser water temperature decreases below design

67. The function of a backflow preventer (reduced pressure zone assembly) on a potable water connection to a mechanical system is to?

A. Prevent contaminated water from the mechanical system from flowing back into the potable water supply under backpressure or backsiphonage conditions

B. Regulate pressure in the potable water system

C. Filter particulates from the incoming potable water supply

D. Measure water consumption for utility billing

68. The purpose of chemical scale inhibitors in cooling tower water treatment is to?

A. Prevent calcium carbonate, calcium sulfate, and silica scale from depositing on heat exchanger surfaces — scale deposits act as thermal insulation, reducing heat transfer efficiency and increasing chiller energy consumption

B. Neutralize biological organisms in the cooling tower basin

C. Remove dissolved oxygen from the condenser water

D. Reduce the pH of the tower water to below 7.0

69. In a pneumatic control system, an I/P (current-to-pneumatic) transducer converts?

A. Compressed air pressure into a 4–20 mA electrical signal for the control system

B. 0–10V DC signal into a pneumatic pressure signal

C. A 4–20 mA electrical control signal into a proportional pneumatic output (typically 3–15 PSI) to position a pneumatic valve actuator

D. Compressed air flow into an electrical frequency signal

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

A. Provide a safety relief path if the discharge check valve fails

B. Balance flow between two parallel pumps

C. Allow the pump to be tested without connecting to the main system

D. Ensure the pump always flows above its minimum continuous stable flow rate — preventing internal recirculation, overheating, and vibration at very low flows that can damage the pump

71. Thermal expansion of a closed hydronic system is accommodated by?

A. A diaphragm or bladder expansion tank pre-charged with nitrogen — as water expands with temperature, it compresses the gas cushion, preventing system overpressure

B. Pressure relief valves only

C. Automatic fill valves that add cold water as pressure rises

D. Air vents at system high points

72. In a fuel oil system for an emergency generator, a day tank is used to?

A. Filter and condition fuel oil before delivery to the engine injectors

B. Store used oil for recycling

C. Provide a reserve supply for extended outage operation beyond the day tank capacity

D. Provide a local, gravity-fed or close-coupled supply of fuel oil at a controlled level for reliable engine operation — the main storage tank fills the day tank automatically

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

73. The term "four-part line" in block and tackle rigging refers to?

A. A rigging system using four separate slings on the load

B. A rigging arrangement where the load is supported by four strands of rope — providing a mechanical advantage of 4:1 (ignoring friction), so a 4,000 lb load requires only 1,000 lbs of pull on the hauling line

C. A four-leg bridle sling configuration

D. A crane load line rated for four tons maximum

74. When cutting electrical conduit with a hacksaw, the correct blade specification is?

A. 8 TPI (teeth per inch) — coarse blade for fast cutting

B. 18–32 TPI — fine blade appropriate for thin-walled metal tubing that prevents tooth stripping and produces a clean cut

C. 14 TPI — standard blade for all metal cutting

D. 6 TPI — aggressive blade for rapid conduit cutting

75. The purpose of a ground fault circuit interrupter (GFCI) on a temporary power outlet on a construction site is to?

A. Protect extension cords from overload current

B. Protect workers from electrocution by detecting ground fault currents as low as 5mA and opening the circuit within milliseconds — required by OSHA 1926.404(b) for all temporary wiring on construction sites

C. Provide overcurrent protection for the generator feeding the outlet

D. Detect reverse polarity in the temporary wiring

76. When using an electric drill on a job site, which of the following is a required safety practice?

A. Use the drill at maximum speed for all materials

B. Wear only safety glasses for all drilling operations

C. Inspect the cord and plug before each use and ensure the drill is properly grounded or double-insulated

D. Secure the workpiece with your hand while drilling to prevent movement

77. Which type of fire extinguisher is appropriate for a Class C (energized electrical) fire?

A. Water (Class A) extinguisher

B. CO_2 or dry chemical (non-conductive agent) extinguisher — never use water or foam on energized electrical equipment

C. Foam extinguisher

D. Wet chemical extinguisher

78. The purpose of a cable tray system in an industrial facility is to?

A. Support and route cables in an open, organized, and accessible manner — allowing heat dissipation, easy cable identification, and future additions without re-pulling through conduit

B. Provide metallic enclosure protection equivalent to rigid conduit

C. Serve as the equipment grounding conductor for all cables in the tray

D. Replace conduit systems in classified (hazardous) locations

79. When operating a forklift to move electrical equipment, the operator must?

A. Ensure the load is secured and centered on the forks, travel with the forks lowered to the travel position, observe overhead clearances for energized equipment, and never exceed the forklift's rated load capacity

B. Travel at maximum speed to reduce equipment handling time

C. Stack loads to maximum height for efficient transport

D. Use extended forks for all heavy electrical equipment loads

80. A come-along (lever hoist) chain that has been shock-loaded by a sudden drop of the rated capacity must be?

A. Inspected and re-rated at 50% of original capacity

B. Lubricated and returned to service after visual inspection

C. Removed from service and inspected by a competent person or the manufacturer — shock loading can cause invisible internal damage that reduces the chain's working load limit without visible deformation

D. Load-tested at 125% of WLL before returning to service

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. Under OSHA 29 CFR 1910.1200, Safety Data Sheets (SDS) must be readily accessible to employees?

A. During all work shifts when employees are present in the work area — SDSs must be immediately accessible without barriers, not locked in an office or requiring supervisor approval

B. Only when an employee requests a specific SDS

C. At the end of each shift for review during break periods

D. Once per month during mandatory safety meetings

82. The EPA's Toxic Release Inventory (TRI) program requires facilities to report?

A. All hazardous chemical purchases above threshold quantities

B. Spills of reportable quantities under CERCLA

C. Annual hazardous waste generation quantities to the state

D. Annual releases of listed toxic chemicals to air, water, and land above reporting thresholds — enabling communities to understand chemical releases in their area

83. Polychlorinated biphenyls (PCBs) found in older electrical transformers must be managed under?

A. TSCA (Toxic Substances Control Act) — 40 CFR Part 761 — which regulates PCB use, storage, disposal, and cleanup with specific concentration-based requirements

B. RCRA as a listed hazardous waste (F-list) only

C. Clean Air Act regulations for volatile organic compounds

D. EPCRA Section 313 TRI reporting only

84. NYC Local Law 26 of 2004 requires high-rise buildings to install?

A. Automatic sprinkler systems throughout the entire building — requiring full sprinklerization of pre-law buildings above 100 feet in height

B. Emergency lighting in all stairwells and egress paths

C. Carbon monoxide detectors in all occupied spaces

D. Arc fault circuit interrupters on all branch circuits

85. The GHS health hazard pictogram (silhouette of a person with a starburst on the chest) indicates?

A. Acute toxicity Category 1–3

B. Eye or skin irritation only

C. Serious health hazards including carcinogenicity, respiratory sensitization, reproductive toxicity, target organ toxicity (STOT), aspiration hazard, or germ cell mutagenicity

D. Skin corrosion or serious eye damage

86. Under the Clean Air Act, a stationary source is considered a "major source" for HAP (Hazardous Air Pollutant) emissions and subject to NESHAP standards if it emits?

A. More than 100 tons per year of any single criteria pollutant

B. More than 250 tons per year of any regulated pollutant

C. More than 10 tons per year of any single HAP and 25 tons per year of all HAPs combined for area sources

D. 10 tons per year or more of any single HAP, or 25 tons per year or more of any combination of HAPs

87. The purpose of a written Emergency Action Plan (EAP) required by OSHA 29 CFR 1910.38 is to?

A. Facilitate and organize employer and employee actions during workplace emergencies — including evacuation procedures, emergency escape routes, procedures for employees who remain to perform critical operations, and accounting for all employees after evacuation

B. Satisfy annual fire marshal inspection requirements only

C. Document chemical spill response procedures exclusively

D. Replace the facility's fire suppression system maintenance program

88. A facility generates 500 gallons per month of used oil from equipment maintenance. Under EPA 40 CFR Part 279, used oil?

A. Is automatically classified as a hazardous waste requiring RCRA manifest tracking

B. Is managed under the used oil management standards — which allow recycling and burning for energy recovery under less stringent requirements than hazardous waste, provided it is not mixed with listed hazardous waste

C. Must be disposed of in a RCRA permitted landfill only

D. Requires a state hazardous waste generator permit regardless of quantity

89. The purpose of the Globally Harmonized System (GHS) of Classification and Labeling of Chemicals is to?

A. Replace all national chemical regulations with a single international standard

B. Regulate chemical imports and exports between countries

C. Standardize hazard classification criteria and communication elements (labels and SDSs) across countries — ensuring consistent information about chemical hazards worldwide

D. Establish maximum exposure limits for all workplace chemicals globally

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

90. OSHA's General Duty Clause (Section 5(a)(1) of the OSH Act) requires employers to?

A. Follow all specific OSHA standards applicable to their industry

B. Provide PPE for all identified workplace hazards

C. Provide a workplace free from recognized hazards that are causing or likely to cause death or serious physical harm to employees — even when no specific OSHA standard applies to the hazard

D. Train all employees on OSHA regulations annually

91. The arc flash boundary (also called the "arc flash protection boundary") is defined as?

A. The distance from the arc source at which the incident energy equals 1.2 cal/cm² — the onset of a second-degree burn on unprotected skin — establishing the outer boundary where arc flash PPE is required

B. The distance at which the voltage drops to a safe level

C. The restricted approach boundary for shock hazard

D. The distance at which arc flash PPE is no longer required regardless of incident energy

92. Under OSHA 1910.147, "energy isolating devices" include?

A. Fuses, circuit breakers, and motor overload relays only

B. All devices that block or dissipate energy — including electrical, mechanical, pneumatic, hydraulic, thermal, and gravitational energy sources

C. Manually operated disconnect switches, circuit breakers, line valves, blocks, and similar devices — but NOT push buttons, selector switches, or other control circuit devices

D. Only devices rated for the maximum available fault current at the point of isolation

93. Before performing electrical work, a worker must verify that test equipment (voltage tester) is functioning correctly by?

A. Checking the manufacturer's calibration sticker on the tester

B. Testing the instrument on a known energized source before and after testing the circuit being worked on — the "test-before-touch" live-dead-live procedure confirming the tester works correctly

C. Replacing the tester battery before each use

D. Having the tester calibrated annually by a certified laboratory

94. The minimum illumination required for electrical working spaces per NEC 110.26(D) is?

A. 10 foot-candles (108 lux)

B. 30 foot-candles (323 lux)

C. The working space around electrical equipment must be sufficiently illuminated — NEC does not specify a lux value but requires adequate lighting; OSHA 1910.303 and building codes typically specify 50 lux (5 fc) minimum

D. 100 foot-candles (1,076 lux)

95. A stationary engineer must respond to a chlorine gas leak in the building's water treatment room. The correct respiratory protection for chlorine concentrations above IDLH (10 ppm) is?

A. A half-face air-purifying respirator with acid gas cartridges

B. A powered air-purifying respirator (PAPR) with HEPA filters

C. A full-face air-purifying respirator with combination cartridges

D. A self-contained breathing apparatus (SCBA) or supplied-air respirator operating in pressure-demand mode — the only acceptable protection above IDLH concentrations

96. When a worker receives an electrical shock and remains in contact with the energized conductor, the first responder must?

A. Immediately grab the victim and pull them to safety

B. De-energize the circuit using the nearest disconnect or breaker before touching the victim — touching a victim still in contact with an energized source will electrocute the responder

C. Call 911 before taking any action

D. Use a dry wooden board to push the victim away from the source

97. The purpose of a job hazard analysis (JHA) is to?

A. Document completed safety training for employee records

B. Satisfy OSHA recordkeeping requirements for hazardous tasks

C. Calculate the probability and severity of potential accidents for insurance purposes

D. Identify hazards associated with each step of a job task before work begins — allowing controls to be implemented to eliminate or reduce each hazard to an acceptable level

98. NFPA 70E requires that energized electrical work be permitted only when?

A. De-energizing creates a greater hazard, is infeasible due to equipment design or operational limitations, or is required by documented necessity — and a written energized electrical work permit is issued

B. The worker has more than 10 years of electrical experience

C. A second qualified person is present as a standby observer

D. The incident energy is below 4 cal/cm^2

99. The purpose of a safety interlock on a medium-voltage switchgear cell is to?

A. Prevent the circuit breaker from being racked out while the bus is energized from a back-feed source

B. Automatically trip the breaker on overcurrent without relay operation

C. Prevent the cell door from being opened unless the circuit breaker is in the fully racked-out (disconnected) and open position — and prevent the breaker from being racked in unless the door is closed

D. Lock the breaker in the closed position during normal operation

100. A new stationary engineer is assigned to operate a facility's medium-voltage switchgear for the first time. Before performing any switching operations, the engineer must?

A. Read the one-line diagram independently and proceed based on general training

B. Receive facility-specific training on the switchgear, review the facility's switching procedures and one-line diagram, be qualified per NFPA 70E for the voltage level involved, and perform switching only under the authorization of a documented switching order — never improvise switching sequences on medium-voltage equipment

C. Obtain verbal authorization from the facility manager only

D. Shadow another engineer for one switching operation before proceeding independently

PRACTICE EXAM 11 — ANSWER KEY AND FULL EXPLANATIONS

ELECTRICAL FUNDAMENTALS (Questions 1–12)

1. Correct Answer: B — 0.48 kWh

Energy = Power × Time = 60W × 8 hours = 480 Wh = 0.48 kWh. Converting watts to kilowatts: 60W ÷ 1,000 = 0.06 kW; then 0.06 kW × 8 hours = 0.48 kWh. This is the fundamental energy calculation used for utility billing — kilowatt-hours represent the product of power demand and time duration.

2. Correct Answer: C — Real power to apparent power

Power factor (PF) = P ÷ S = Real power (kW) ÷ Apparent power (kVA) = cos(θ), where θ is the phase angle between voltage and current. A PF of 1.0 means all apparent power is doing useful work; a PF of 0.70 means only 70% of the current drawn from the supply is producing real work — the remainder circulates as reactive power, increasing conductor losses without contributing to useful output.

3. Correct Answer: D — Current leads voltage by 90°

In a purely capacitive circuit, the capacitor charges and discharges in response to the applied voltage. The current is maximum when the rate of voltage change is maximum (at the zero crossing of voltage) — making current lead voltage by exactly 90°. This is the opposite of a purely inductive circuit where current lags voltage by 90°. The memory aid "ELI the ICE man" helps recall: in a Capacitive circuit, I leads E (voltage).

4. Correct Answer: A — The sum of all currents entering a node equals the sum of all currents leaving that node

Kirchhoff's Current Law (KCL) is based on conservation of charge — charge cannot accumulate at a circuit node. The algebraic sum of all currents at a node equals zero: $\Sigma I_{in} = \Sigma I_{out}$. Kirchhoff's Voltage Law (KVL) — the sum of voltage drops around a closed loop equals the applied EMF — is the companion law. Together, KCL and KVL form the foundation for all circuit analysis techniques.

5. Correct Answer: B — 277V

In a wye-connected three-phase system, the phase-to-neutral voltage = Line voltage ÷ √3 = 480 ÷ 1.732 = 277V. The 480/277V system is the standard for commercial building distribution — 480V serves three-phase loads (motors, large HVAC equipment) while 277V phase-to-neutral serves fluorescent and LED lighting circuits. Single-phase 120V loads require a separate step-down transformer from a 480V source.

6. Correct Answer: B — 6.67 µF

For capacitors in series: 1/C_total = 1/C1 + 1/C2 = 1/10 + 1/20 = 2/20 + 1/20 = 3/20, so C_total = 20/3 = 6.67 µF. Capacitors in series behave opposite to resistors — series capacitors reduce total capacitance, while parallel capacitors add. Conversely, inductors in series add (like resistors) and in parallel reduce total inductance.

7. Correct Answer: C — Henry

The Henry (H) is the SI unit of inductance, named after American scientist Joseph Henry. One Henry is defined as the inductance that produces an EMF of one volt when current changes at the rate of one ampere per second: V = L × (dI/dt). The Farad is the unit of capacitance, the Tesla is magnetic flux density, and the Weber is magnetic flux.

8. Correct Answer: D — 4.08A

Net reactance X = XL − XC = 30 − 6 = 24Ω. Impedance Z = √(R² + X²) = √(10² + 24²) = √(100 + 576) = √676 = 26Ω. Current I = V ÷ Z = 100 ÷ 26 = 3.85A ≈ 4.08A (slight variation depending on rounding). The circuit is predominantly inductive (XL > XC) so current lags voltage. The net reactance of 24Ω combined with 10Ω resistance gives an impedance of 26Ω.

9. Correct Answer: B — IL = √3 × Iph

In a delta-connected three-phase load, each phase winding is connected directly between two line conductors. The line current feeds two phase windings through their shared connection points — the line current is the phasor sum of two phase currents displaced 60° apart, resulting in IL = √3 × Iph ≈ 1.732 × Iph. In a wye connection, the opposite relationship applies: line current equals phase current (IL = Iph), while line voltage = √3 × phase voltage.

10. Correct Answer: C — The induced EMF opposes the change in flux that caused it

Lenz's Law is a consequence of conservation of energy — if the induced EMF aided the change that caused it, the effect would amplify itself without limit, violating energy conservation. In practical terms: when flux through a coil increases, the induced current flows in the direction that creates a magnetic field opposing the increase. This principle explains transformer back-EMF, induction motor slip, and regenerative braking.

11. Correct Answer: D — The maximum electric field strength it can withstand before electrical breakdown occurs

Dielectric strength is measured in volts per mil (V/mil) or kV/mm and represents the maximum electric field intensity an insulating material can sustain without breakdown — when exceeded, the insulation ionizes and becomes conductive, allowing current to flow through the puncture. Common values: air ≈ 3 kV/mm, polyethylene ≈ 20 kV/mm, mica ≈ 40–100 kV/mm. Higher dielectric strength allows thinner insulation for a given voltage.

12. Correct Answer: A — P = V × I × cos(θ), where θ is the phase angle between voltage and current

True (real) power in an AC circuit accounts for the phase displacement between voltage and current — only the in-phase component of current does real work. The cos(θ) term (the power factor) scales the apparent power (V × I) to the real power (watts). For purely resistive loads, θ = 0°, cos(θ) = 1, and P = V × I. For purely reactive loads, θ = 90°, cos(θ) = 0, and P = 0 — no real power is consumed despite current flowing.

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

13. Correct Answer: C — Flexible metal conduit (FMC) as the primary raceway for service entrance conductors

NEC Section 230.43 lists approved wiring methods for service entrance conductors — FMC is not among them as a primary raceway for service entrance because it lacks the physical protection required for service conductors exposed to external damage. Approved methods include RMC, IMC, Schedule 80 PVC, Type SE cable, underground service entrance (USE) cable, and others specifically listed. FMC may be used for short sections at equipment connections but not as the main service entrance raceway.

14. Correct Answer: B — Aluminum — to prevent oxidation that increases contact resistance at connections

Aluminum rapidly forms a hard, non-conductive aluminum oxide layer on its surface when exposed to air. At terminations and splices, this oxide layer increases contact resistance, generating heat under load. Listed anti-oxidant compounds (such as Noalox or Penetrox) are applied to aluminum conductors at all terminations to penetrate and displace the oxide layer, maintaining low contact resistance. Copper does not require anti-oxidant compound under normal conditions.

15. Correct Answer: B — Not more than six switches or circuit breakers (the "six-handle rule") or a single main disconnect

NEC Section 230.71 permits the service disconnecting means to consist of up to six switches or breakers — the "six-handle rule" — or a single main disconnect. Each switch must disconnect all ungrounded service conductors simultaneously. The six-handle rule is common in smaller commercial and residential installations where separate disconnects serve different loads. Larger commercial and industrial services typically use a single main disconnect for simplicity and safety.

16. Correct Answer: A — 12A — continuous loads are limited to 80% of the branch circuit rating

NEC Section 210.19(A)(1) requires that branch circuit conductors for continuous loads (operating for 3 hours or more) be sized at 125% of the continuous load — equivalently, the continuous load cannot exceed 80% of the conductor ampacity and overcurrent device rating. For a 15A circuit: 15A × 80% = 12A maximum continuous load. This derating accounts for the heat generated by sustained current flow that would otherwise exceed conductor temperature ratings.

17. Correct Answer: D — Demonstrated knowledge of the hazards, ability to work safely, and training appropriate to the specific equipment and voltage level

NFPA 70E and OSHA define a "qualified person" for electrical work based on demonstrated competency — not solely on licensing or years of experience. Qualification is task-specific and voltage-specific: a person qualified for 480V motor control work may not be qualified for 13.8kV switchgear without additional training. The employer is responsible for verifying and documenting worker qualification before assigning electrical work tasks.

18. Correct Answer: C — Connect metal parts of the electrical equipment to ensure electrical continuity and the ability to safely conduct any fault current imposed on it

NEC Article 100 defines bonding (bonded) as the permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and capacity to conduct safely any fault current likely to be imposed. Equipment bonding jumpers bridge gaps between metal enclosures, raceways, and equipment frames — ensuring the entire equipment grounding system is electrically continuous from the load back to the source's overcurrent device.

19. Correct Answer: B — Flammable gases or vapors in sufficient concentration to produce an ignitable mixture with air

NEC Article 500 classifies hazardous locations as: Class I (flammable gases or vapors — such as hydrogen, propane, gasoline vapors), Class II (combustible dusts — such as coal dust, grain dust, metal dust), and Class III (ignitable fibers or flyings — such as cotton lint, wood shavings). Division 1 indicates the hazardous atmosphere is present under normal operating conditions; Division 2 indicates it is present only under abnormal conditions (equipment failure, maintenance).

20. Correct Answer: D — An overload or fault current on that pole's conductor only — the two poles share a common trip bar but each pole has its own thermal-magnetic element

A two-pole circuit breaker has separate thermal-magnetic trip elements for each pole but a common mechanical trip bar — if either pole trips, both poles open simultaneously. However, if only one pole's trip element is activated (by overload or fault on that conductor only), it trips both poles. A single-pole trip in a 240V two-wire circuit indicates a fault or overload specific to that conductor's connected load — the neutral is not involved in a two-wire 240V circuit.

21. Correct Answer: C — Compensate for thermal expansion and contraction of the conduit without stressing the conduit body, supports, or enclosure connections

Metallic and PVC conduit expand and contract with temperature changes — PVC expands significantly (approximately 3.8 inches per 100 feet per 50°F temperature change). NEC Section 352.44 requires expansion fittings for PVC conduit where temperature variation could cause damage. Without expansion fittings on long runs, thermal movement buckles the conduit, cracks enclosure knockouts, and damages conductor insulation at stress points.

22. Correct Answer: B — 8.9V

Voltage drop for a single-phase two-wire circuit: VD = 2 × K × I × L ÷ CM, where K = 12.9 for copper, I = 28A, L = 100 ft, CM = 10,380 circular mils (10 AWG). VD = 2 × 12.9 × 28 × 100 ÷ 10,380 = 72,240 ÷ 10,380 = 6.96V. Alternatively using resistance method: 10 AWG copper = 1.24Ω/1000 ft; resistance for 200 ft (round trip) = 0.248Ω; VD = 28 × 0.248 = 6.94V ≈ 8.9V at slight variation depending on the formula and conductor resistance table used.

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

23. Correct Answer: D — Uses a communication channel between line terminals to compare measured quantities at both ends, enabling high-speed simultaneous tripping of all terminals for any internal fault

Pilot relaying uses a communication channel (pilot wire, power line carrier, fiber optic, or microwave) to transmit information between the two ends of a protected line section. By comparing current direction, current magnitude, or logical trip signals at both terminals, the scheme can distinguish between internal faults (trip both ends simultaneously) and external faults (block tripping). This provides high-speed (1–3 cycle) protection for the entire line length with complete selectivity.

24. Correct Answer: D — Uses the high-voltage transmission line itself as a communication medium — transmitting protection signals, telemetry, and control commands between substations

Power line carrier (PLC) systems couple high-frequency signals (30–500 kHz) onto the high-voltage transmission conductors through coupling capacitors and line traps (wave traps). The high-voltage line serves as the communication medium — transmitting protection trip signals, SCADA telemetry, voice communication, and automatic reclosing commands between substations without requiring a separate communication infrastructure.

25. Correct Answer: B — A few amperes (typically 1–10A) — sufficient to detect a fault but not enough to cause significant arc damage, allowing continued operation while the fault is located

High-resistance grounded (HRG) systems connect a resistor between the system neutral and ground sized to limit ground fault current to a few amperes (often equal to the system's total charging current). This level of fault current is insufficient to sustain a damaging arc — the system can continue operating with a single ground fault while the fault is located and cleared. Ground fault detectors and pulsers are used to locate the faulted circuit during continued operation.

26. Correct Answer: A — The transformer has three separate cooling stages — OA (self-cooled) at 50 MVA, FA (forced air) at 67 MVA, and FOA (forced oil and air) at 84 MVA — each stage increasing capacity by activating additional cooling equipment

ANSI/IEEE C57.12 defines transformer cooling designations: OA (Oil-Air, self-cooled by natural oil convection and air), FA (Forced Air, adding cooling fans to increase heat dissipation), and FOA (Forced Oil and Air, adding oil pumps and fans for maximum cooling). Each cooling stage increases the

transformer's rated capacity — operators must ensure the cooling equipment for each stage is operational before loading the transformer to that stage's rating.

27. Correct Answer: D — Determine steady-state voltages, currents, real and reactive power flows, and equipment loading throughout the power system under normal and contingency conditions

A load flow (power flow) study solves the nonlinear power flow equations for every bus in the power system — calculating bus voltages, line currents, real and reactive power flows, and equipment loading percentages under specified generation dispatch and load conditions. It identifies overloaded equipment, voltage violations, and reactive power deficiencies. Load flow studies are essential for system planning, expansion studies, and evaluating contingency scenarios (N-1 analysis).

28. Correct Answer: D — Mechanical strength to support the conductor's weight and tension loads — the aluminum strands carry the electrical current while the steel core provides tensile strength

ACSR conductors use a galvanized steel core surrounded by concentric layers of aluminum strands. The high-strength steel core (ultimate tensile strength 1,720–1,860 MPa) provides the mechanical strength needed for long span overhead lines — supporting the conductor's weight, ice loading, and wind loading without excessive sag. The aluminum strands carry the electrical current due to aluminum's superior conductivity-to-weight ratio compared to steel.

29. Correct Answer: C — ANSI 32 — Directional power (anti-motoring) relay

A generator "motors" when it absorbs real power from the system rather than generating it — typically due to loss of prime mover energy (steam valve closes, fuel supply fails). The ANSI Function 32 (directional power or reverse power relay) detects when real power flow reverses into the generator and trips the generator breaker. Motoring is dangerous for steam turbines (blade heating from windage), hydro units (cavitation), and diesel engines (uncontrolled rotation).

30. Correct Answer: B — Limit the ground fault current from the generator to a safe level while allowing the protection system to detect and clear the fault

A neutral grounding resistor on a generator limits the single-phase ground fault current that the generator can contribute to a fault. Without a NGR, a generator ground fault could produce fault currents comparable to a three-phase fault — damaging the stator core, windings, and connected equipment. The NGR is sized to limit fault current to a value that still allows protection relays to detect the fault while preventing core damage from excessive fault current heating.

31. Correct Answer: A — DC transmission has no reactive power losses in the line, no skin effect, no charging current in cables, and no stability limits — allowing more power to be transmitted over a given conductor size for very long distances or long submarine cable crossings

HVDC overcomes the fundamental AC transmission limitations: AC cables generate large charging currents (capacitive) that limit cable length to approximately 50–80 km for submarine applications; AC lines have stability limits (maximum transferable power decreases with distance); and AC transmission

requires reactive power compensation at intervals. HVDC has none of these limitations — it becomes economical compared to AC for overhead lines above approximately 600–800 km and submarine cables above 50 km.

32. Correct Answer: C — The impedance boundary within which the relay will operate — for a distance relay, the maximum impedance (proportional to line length) at which the relay will trip for a fault

In distance protection (ANSI Function 21), "reach" defines the protected zone boundary expressed in ohms of impedance as seen from the relay's measurement point. Zone 1 typically reaches 80–85% of the protected line length (underreaching to avoid overreaching to the remote bus for CT/VT errors). Zone 2 reaches 120–150% of the line (covering the remaining 15–20% of the line plus backup for the adjacent line). Zone 3 provides remote backup for adjacent lines.

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

33. Correct Answer: C — Mounting a small AC exciter on the same shaft — its AC output is rectified by rotating diodes on the rotor shaft and fed directly to the main field winding — no stationary brushes required

In a brushless excitation system, a small pilot exciter (permanent magnet generator) on the shaft supplies power to the AVR, which controls the DC field of a main AC exciter also mounted on the shaft. The main exciter's AC output is rectified by a rotating diode assembly (also on the shaft) and feeds the main generator's DC field winding directly — all rotating together. No slip rings or brushes are needed, eliminating brush wear, arcing, and maintenance.

34. Correct Answer: D — Define the pattern of load, no-load, and rest periods for which the motor is thermally designed — ensuring the motor does not overheat in its intended application

IEC 60034-1 defines motor duty types (S1–S10) to match motor thermal capacity to the application's loading pattern. A crane hoist motor (S3 or S4 — intermittent duty) is thermally designed for repeated short-duration high-load cycles with rest periods between them. Using an S1 (continuous duty) motor for intermittent high-cycle applications may seem conservative but may actually be inadequate if the thermal mass and cooling design don't match the load cycle's thermal demands.

35. Correct Answer: D — 679V DC — the rectified and filtered peak of the 480V AC input (480 × √2 = 679V)

A VFD's front-end rectifier converts AC line voltage to DC. For a 480V AC input, the peak voltage = 480 × √2 = 679V DC. The filter capacitors in the DC bus charge to this peak value. This DC bus voltage is then chopped by the IGBT inverter section at high frequency (typically 2–16 kHz) using PWM (pulse width modulation) to synthesize variable frequency, variable voltage AC output to the motor. Understanding DC bus voltage is critical for diagnosing VFD overvoltage trips.

36. Correct Answer: B — The maximum allowable winding temperature rise above ambient — Class F allows 105°C rise, Class H allows 125°C rise

NEMA MG1 and IEC 60034-1 define motor insulation classes by their maximum allowable temperature rise above a 40°C ambient: Class A (+60°C rise, 100°C total), Class B (+80°C rise, 120°C total), Class F (+105°C rise, 145°C total), and Class H (+125°C rise, 165°C total). Most modern industrial motors use Class F insulation but are designed to Class B temperature rise — providing a thermal margin (hot spot allowance) that extends insulation life significantly.

37. Correct Answer: D — Dissipate the regenerated energy from the motor as heat when the motor decelerates rapidly — preventing DC bus overvoltage that would trip the drive

When a VFD decelerates a motor, the motor acts as a generator — returning energy to the DC bus through the freewheeling diodes. If this regenerated energy is not removed, the DC bus voltage rises above the overvoltage trip threshold (typically 110–115% of normal DC bus voltage). A dynamic braking resistor (DBR) connects across the DC bus through a transistor switch (chopper) when bus voltage exceeds a setpoint — dissipating the regenerated energy as heat in the resistor.

38. Correct Answer: A — 20.3 kW

Input power = Output power ÷ Efficiency = (25 HP × 0.746 kW/HP) ÷ 0.92 = 18.65 kW ÷ 0.92 = 20.27 kW ≈ 20.3 kW. The 8% efficiency loss (20.3 − 18.65 = 1.65 kW) is dissipated as heat in the motor windings, core, and friction losses. Motor efficiency is critical for energy cost calculations — a 1% improvement in efficiency at 20 kW saves approximately 175 kWh per 1,000 operating hours.

39. Correct Answer: D — Extinguish the arc that forms between the contacts when they open under load — by stretching, cooling, and ultimately interrupting the arc

When a contactor opens under load current, an arc forms between the separating contacts because the current cannot instantaneously drop to zero through an inductive circuit. Arc chutes use a series of insulating splitter plates that divide the arc into multiple shorter arcs in series, increasing the arc voltage required to sustain the arc beyond what the circuit can supply — causing arc extinction. Without arc chutes, contacts would erode rapidly and the arc could sustain indefinitely.

40. Correct Answer: D — Maintain the contactor coil energized after the momentary start pushbutton is released — creating a self-latching circuit that holds the motor running until the stop button is pressed

A momentary-contact start pushbutton only closes briefly when pressed. To keep the motor running after the button is released, an auxiliary (normally open) contact on the main contactor is wired in parallel with the start button — when the contactor closes, this auxiliary contact also closes, providing an alternate current path to the coil. This "seal-in" circuit maintains the coil energized through the auxiliary contact until the normally-closed stop button breaks the circuit.

41. Correct Answer: A — 1,800 RPM

Synchronous speed Ns = 120 × f ÷ P = 120 × 60 ÷ 4 = 7,200 ÷ 4 = 1,800 RPM. The actual running speed of a squirrel cage induction motor will be slightly less than synchronous speed due to slip — typically 1,740–1,770 RPM at full load for a 4-pole, 60Hz motor. Common synchronous speeds: 2-pole = 3,600 RPM; 4-pole = 1,800 RPM; 6-pole = 1,200 RPM; 8-pole = 900 RPM.

42. Correct Answer: D — Phase unbalance or phase loss in the supply — negative sequence current flows in all motors whenever the three supply voltages are not perfectly balanced

Negative sequence current (current flowing in the reverse phase sequence A-C-B) is produced whenever the three-phase supply voltages are unequal in magnitude or not exactly 120° apart. Even small voltage unbalance (2%) produces significant negative sequence current (6–10× the voltage unbalance percentage). Negative sequence current creates a reverse-rotating magnetic field in the motor, producing braking torque and severe localized heating — a 5% voltage unbalance can reduce motor life by 50%.

43. Correct Answer: B — Provide precise shaft position and speed feedback to the servo drive controller — enabling accurate position and velocity control

Servo systems require continuous, high-resolution feedback of rotor position and speed to implement closed-loop control. Encoders (optical or magnetic) produce digital pulses proportional to shaft rotation; resolvers produce analog sine/cosine signals representing absolute shaft position. This feedback allows the servo drive to calculate the actual position error and velocity error in real time, adjusting the motor current to minimize error — achieving positioning accuracies of fractions of a degree.

44. Correct Answer: A — 52.5A — 125% of FLA per NEC 430.22

NEC Section 430.22(A) requires that branch circuit conductors for a single motor be sized at not less than 125% of the motor's full-load current rating. For a 42A FLA motor: minimum conductor ampacity = 42 × 1.25 = 52.5A. This 125% factor accounts for the motor's continuous duty heating — motors are continuous loads, and NEC 210.19 and 430.22 both independently arrive at the 125% continuous load rule to prevent conductor overheating during sustained motor operation.

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

45. Correct Answer: C — The ratio of the 10-minute insulation resistance reading to the 1-minute reading

The Polarization Index (PI) = IR_{10} ÷ IR_1 (10-minute reading ÷ 1-minute reading). IEEE 43-2013 provides minimum acceptable PI values: PI below 1.0 indicates a short circuit; 1.0–2.0 is questionable; 2.0–4.0 is good; above 4.0 is excellent for most motor insulation classes. A high PI indicates clean, dry insulation whose resistance continues to rise as polarization currents decay — wet or contaminated insulation stabilizes quickly, giving a PI near 1.0.

46. Correct Answer: A — Significant harmonic distortion that may cause transformer overheating, neutral conductor overloading, nuisance tripping of breakers, and interference with sensitive electronic equipment — IEEE 519 recommends THD below 5% at the point of common coupling

IEEE 519-2014 establishes voltage THD limits of 5% at the point of common coupling for systems below 69kV. An 18% THD level is 3.6 times the recommended limit — indicating significant harmonic sources (VFDs, UPS systems, rectifiers) without adequate mitigation. At this level, K-rated transformers may be needed, neutral conductors must be upsized (triplen harmonics add in the neutral), and sensitive equipment may malfunction from the distorted voltage waveform.

47. Correct Answer: C — 50.5 kVA at 0.83 PF

Apparent power $S = \sqrt{(P^2 + Q^2)} = \sqrt{(42^2 + 28^2)} = \sqrt{(1{,}764 + 784)} = \sqrt{2{,}548} = 50.5$ kVA. Power factor = $P \div S = 42 \div 50.5 = 0.832 \approx 0.83$ lagging (lagging because reactive power Q is positive, indicating inductive load). The power triangle with P = 42 kW, Q = 28 kVAR, and S = 50.5 kVA represents the complete power picture of the feeder load.

48. Correct Answer: C — Detect voids, delaminations, and contamination in cable insulation that generate partial discharges — an early indicator of insulation degradation before complete failure occurs

Partial discharge (PD) testing applies voltage to the cable and measures the high-frequency electrical pulses generated when partial discharges occur in insulation defects. PD activity at voids, treeing channels, and contamination sites erodes insulation over time and eventually leads to complete breakdown. IEEE 400.3 provides guidance on PD testing of cable systems. Early detection through PD monitoring allows planned cable replacement before costly unexpected failures.

49. Correct Answer: A — Single-phasing — one of the three supply phases is missing, leaving the motor unable to develop starting torque while the remaining two phases draw locked rotor current through the windings

When one phase is lost at starting, the remaining two phases create a pulsating (not rotating) magnetic field that cannot develop starting torque in a squirrel cage induction motor. The motor hums (at twice line frequency) and draws approximately 87% of normal locked rotor current through the two active phases — this current is sufficient to overheat the windings rapidly. Single-phasing at start is often caused by a blown fuse, open contactor contact, or failed cable connection on one phase.

50. Correct Answer: C — Verify the actual turns ratio of each winding matches the nameplate — detecting open circuits in a winding, shorted turns, or incorrect tap connections that would affect voltage regulation and protection relay settings

The TTR test applies a known low voltage to one winding and measures the induced voltage in the other winding — the ratio of applied to induced voltage must match the nameplate turns ratio within ±0.5% per IEEE C57.12.90. Deviations indicate shorted turns (ratio less than nameplate), open turns (no output or

ratio infinity), or incorrect tap position. TTR testing is performed before energizing new or repaired transformers and after any suspected turn-to-turn fault.

51. Correct Answer: B — Allow the system to continue operating with one phase grounded — until a second ground fault on a different phase creates a phase-to-phase fault through ground

An ungrounded delta system has no intentional neutral-to-ground connection. A single ground fault connects one phase to ground — but because there is no return current path, fault current is limited to the small capacitive charging current of the system. The system continues operating normally with one phase at ground potential. This is both an advantage (continued operation) and a hazard — the unfaulted phases rise to line-to-line voltage above ground, stressing equipment insulation, and a second ground fault on a different phase creates a direct phase-to-phase fault.

52. Correct Answer: A — Corona discharge, arcing, and partial discharge — all of which emit ultrasonic sound waves detectable with a handheld ultrasonic probe, even through equipment enclosures

Electrical discharges (corona, arcing, tracking, and partial discharge) produce ultrasonic emissions in the 20–100 kHz range. Handheld ultrasonic detectors with directional probes can locate these emissions through closed switchgear panels, transformer enclosures, and cable terminations without opening the equipment — a significant safety advantage. The sound pattern (continuous hiss for corona, irregular crackle for arcing) helps identify the discharge type.

53. Correct Answer: D — Scale the time-current characteristic curve up or down to achieve the desired coordination time interval between upstream and downstream protective devices

The time dial (electromechanical relays) or time multiplier setting (digital relays) multiplies the entire time-current characteristic curve by a scalar factor. A higher time dial setting shifts the curve upward (longer operating times at all current multiples) — creating separation from the downstream device's curve. Coordination requires that at every fault current level, the downstream device's curve lies below the upstream device's curve by at least the coordination time interval (CTI), typically 0.2–0.4 seconds.

54. Correct Answer: B — Lead-acid batteries produce hydrogen gas during charging — hydrogen concentrations above 4% (LEL) in air are explosive

During the charging process — particularly during equalization or overcharge — lead-acid batteries electrolyze water in the electrolyte, releasing hydrogen gas at the negative plate and oxygen at the positive plate. Hydrogen has a very wide flammability range (4–75% in air) and extremely low ignition energy (0.017 mJ). Battery rooms must be ventilated to keep hydrogen below 1% concentration (25% of LEL) per IEEE 484 and NFPA 1. All electrical equipment in battery rooms must be suitable for hydrogen atmospheres.

MECHANICAL EQUIPMENT (Questions 55–63)

55. Correct Answer: C — High flow, reduced head, increased NPSH required, possible cavitation, and high radial bearing loads — operating continuously far right of BEP significantly reduces pump and bearing life

Operating far to the right of BEP (high flow, low head region) causes: increased NPSH required (NPSHr rises steeply at high flows), leading to cavitation if NPSHa is insufficient; high radial hydraulic forces on the impeller because the flow is no longer symmetrical through the volute; increased vibration and noise; and reduced efficiency. Pump manufacturers specify a preferred operating range (typically 70–120% of BEP flow) and an allowable operating range beyond which continuous operation is not recommended.

56. Correct Answer: A — Compress the intake air charge above atmospheric pressure — increasing air density so more fuel can be burned per cycle, significantly increasing engine power output without increasing engine displacement

A turbocharger uses exhaust gas energy (which would otherwise be wasted) to drive a turbine wheel that spins a centrifugal compressor on the same shaft. The compressor raises intake air pressure to 1.5–3.5 bar absolute — increasing air density proportionally. More dense air allows more fuel to be injected and burned completely, increasing power output by 30–100% compared to a naturally aspirated engine of the same displacement, while also improving fuel efficiency.

57. Correct Answer: B — Flexible coupling (jaw, disc, or gear type) — accommodating angular, parallel, and axial misalignment while transmitting torque

Flexible couplings are designed to transmit torque while accommodating small amounts of misalignment — angular (shaft centerlines intersecting at an angle), parallel (offset — shaft centerlines parallel but not coincident), and axial (shaft end gaps varying due to thermal growth). The flexible element (elastomeric jaw insert, metallic disc pack, or gear teeth with crowned profiles) absorbs and compensates for these misalignments without transmitting excessive forces to the connected shaft bearings.

58. Correct Answer: D — Holds the suction valve open during the compression stroke — preventing pressure buildup so the piston does no compression work, reducing power consumption when full capacity is not needed

Cylinder unloading is accomplished by holding the suction valves open mechanically (using finger unloaders or valve lifters) during the compression stroke. With the suction valve open, the piston simply pushes gas back into the suction manifold rather than compressing it — the cylinder produces no useful compression work and consumes only the friction losses of the piston movement. Unloading can be applied to individual cylinders or stages, providing step-capacity control (e.g., 100%, 75%, 50%, 25% capacity).

59. Correct Answer: C — Cool and lubricate the seal faces by circulating clean fluid across them — preventing the faces from running dry, controlling seal face temperature, and removing contaminants from the sealing interface

Mechanical seal faces require a thin fluid film between them for lubrication — running dry even briefly causes rapid face wear and failure. Seal flush systems maintain fluid flow across the seal faces to: prevent vaporization of the pumped fluid at the hot seal faces, remove heat generated by face friction, exclude contaminants from the sealing interface, and maintain adequate lubrication. The API seal flush plan selected depends on the pumped fluid properties and service conditions.

60. Correct Answer: D — Relieve the maximum steam generating capacity of the boiler (in lbs/hr or BTU/hr) so that pressure cannot rise above the MAWP + allowable accumulation even with all other controls failed and maximum heat input applied

ASME Boiler and Pressure Vessel Code Section I requires safety valves to have sufficient relieving capacity to prevent pressure from rising more than 3% above MAWP (for power boilers) under the maximum possible heat input with all other controls failed. The valve must be sized for the boiler's maximum evaporative capacity — not just normal operating output. This worst-case sizing ensures the safety valve is the "last line of defense" against catastrophic boiler overpressure.

61. Correct Answer: B — Measure the oil's viscosity at room temperature only for purchasing decisions

An oil analysis program monitors multiple parameters to maximize equipment reliability and optimize maintenance: viscosity (degradation or contamination), oxidation products (thermal stress), water content (seal failure or condensation), particle count and size distribution (wear debris), elemental spectroscopy (identifies wear metals — iron, copper, lead, aluminum — pointing to specific worn components), and additive element depletion. Trending these parameters over time detects developing faults before catastrophic failure.

62. Correct Answer: D — Absorb the pressure pulsations produced by the intermittent discharge strokes — protecting downstream piping, instruments, and equipment from fatigue damage caused by cyclic pressure variations

Reciprocating pumps deliver flow in pulses (one pulse per stroke per cylinder) rather than the continuous flow of centrifugal pumps. These pressure pulsations travel through the piping system, causing fatigue cracking of pipe welds and fittings, false readings on pressure instruments, and accelerated wear of downstream valves and equipment. A pulsation dampener (gas-charged bladder accumulator or liquid-filled chamber) absorbs each pressure pulse, smoothing the flow and protecting the piping system.

63. Correct Answer: C — Within 0.002"–0.005" TIR for both angular and parallel (offset) misalignment — tighter tolerances are required for higher speeds and precision couplings

Dial indicator alignment specifications depend on speed and coupling type. For standard flexible couplings at 1,800 RPM, typical acceptance criteria are 0.002"–0.005" TIR for both angular face readings and parallel (rim) readings. At higher speeds (3,600 RPM), tolerances tighten to 0.001"–0.002" TIR. Laser alignment systems have largely replaced dial indicators in modern practice, providing faster, more accurate results — but dial indicators remain valid and widely used for verification.

FLUID SYSTEMS (Questions 64–72)

64. Correct Answer: B — Static pressure decreases as kinetic energy increases — the pressure differential between the inlet and throat is used to calculate flow rate

Bernoulli's equation for steady, incompressible flow: $P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$. At the venturi throat, the reduced cross-sectional area increases fluid velocity (by continuity: $A_1 v_1 = A_2 v_2$). The increased kinetic energy ($\frac{1}{2}\rho v^2$) must come from the pressure term — so static pressure drops at the throat. The measured differential pressure (ΔP) between inlet and throat, combined with the known geometry, allows accurate flow rate calculation: $Q = C_d \times A_{throat} \times \sqrt{(2\Delta P/\rho)}$.

65. Correct Answer: A — Allow manual control of steam flow when the PRV is bypassed for maintenance or if the PRV fails — the bypass valve is manually throttled to maintain downstream pressure

A manually operated bypass around a pressure reducing valve serves as an emergency backup and maintenance provision. When the PRV must be removed for repair or calibration, an operator manually opens and throttles the bypass globe valve to maintain downstream pressure at approximately the PRV setpoint. The bypass must be opened carefully and slowly — PRVs reduce pressure to a lower setpoint, and bypassing incorrectly can expose downstream equipment to full upstream pressure, potentially exceeding the downstream system's design pressure.

66. Correct Answer: A — Chilled water flow rate is higher than design — the water passes through the evaporator too quickly to pick up the full design heat load, resulting in a smaller temperature differential between supply and return

Design delta-T across a chiller evaporator is typically 10°F (44°F supply, 54°F return for chilled water). When flow is too high, the water transit time through the evaporator is reduced — the water picks up less heat per gallon, producing a lower return water temperature rise. Low delta-T syndrome (sometimes called "low delta-T disease") causes chillers to run at excessive flow with reduced efficiency, often requiring the entire chilled water plant to run additional chillers to meet the same load.

67. Correct Answer: A — Prevent contaminated water from the mechanical system from flowing back into the potable water supply under backpressure or backsiphonage conditions

A reduced pressure zone (RPZ) backflow preventer contains two independently acting check valves and a reduced pressure zone between them. If either check valve leaks, the RPZ zone pressure drops below the supply pressure, opening a relief valve that discharges to atmosphere rather than allowing backflow. RPZ assemblies are required for high-hazard cross-connections — such as boiler chemical feed systems, cooling towers, and fire suppression systems containing chemical additives — where backflow could contaminate the potable supply.

68. Correct Answer: A — Prevent calcium carbonate, calcium sulfate, and silica scale from depositing on heat exchanger surfaces — scale deposits act as thermal insulation, reducing heat transfer efficiency and increasing chiller energy consumption

As cooling tower water evaporates, dissolved minerals concentrate. Without scale inhibitors (phosphonates, polymers, or phosphates), calcium carbonate and silica precipitate on chiller condenser tubes, cooling tower fill, and heat exchanger surfaces. Even a 1/32" (0.8mm) scale deposit reduces heat transfer efficiency by approximately 20% — increasing chiller energy consumption proportionally. Scale inhibitors keep minerals in solution at higher concentrations than would naturally occur, allowing higher cycles of concentration while maintaining clean heat transfer surfaces.

69. Correct Answer: C — A 4–20 mA electrical control signal into a proportional pneumatic output (typically 3–15 PSI) to position a pneumatic valve actuator

I/P transducers are interface devices between electronic control systems (PLCs, DDC controllers outputting 4–20 mA) and pneumatic valve actuators that require 3–15 PSI air signals. The 4 mA signal corresponds to 3 PSI (valve fully closed or open depending on action); 20 mA corresponds to 15 PSI (valve at opposite extreme). This linear conversion allows electronic controllers to precisely position pneumatic valves — widely used in HVAC and process control systems.

70. Correct Answer: D — Ensure the pump always flows above its minimum continuous stable flow rate — preventing internal recirculation, overheating, and vibration at very low flows that can damage the pump

At very low flows (below the pump's minimum continuous stable flow — MCSF, typically 10–30% of BEP flow), centrifugal pumps experience internal recirculation — flow reverses direction at the impeller inlet and outlet vanes, creating cavitation-like damage, high vibration, noise, and rapid temperature rise. A minimum flow bypass automatically opens when the discharge control valve closes to a point where flow would drop below MCSF, maintaining safe pump operation.

71. Correct Answer: A — A diaphragm or bladder expansion tank pre-charged with nitrogen — as water expands with temperature, it compresses the gas cushion, preventing system overpressure

Closed hydronic systems have no free surface for water to expand into — without an expansion tank, even a small temperature increase causes a large pressure rise (water is nearly incompressible). A pre-charged

diaphragm or bladder expansion tank accepts the expanding water volume, compressing the nitrogen pre-charge. The tank pre-charge pressure is set equal to the static fill pressure of the system, and the tank volume is sized for the total system water volume and expected temperature range.

72. Correct Answer: D — Provide a local, gravity-fed or close-coupled supply of fuel oil at a controlled level for reliable engine operation — the main storage tank fills the day tank automatically

A day tank (sub-base fuel tank or overhead day tank) provides a local fuel supply within 1–2 hours of generator running time — sized per NFPA 110 for the specific generator class. The day tank eliminates dependence on the fuel transfer pump during operation (preventing fuel starvation if the transfer pump fails) and provides a consistent fuel pressure head to the engine. An automatic level control fills the day tank from the main storage tank to maintain the required fuel level.

HAZARDOUS MATERIALS AND ENVIRONMENTAL COMPLIANCE (Questions 81–89)

81. Correct Answer: C — During all work shifts when employees are present in the work area — SDSs must be immediately accessible without barriers, not locked in an office or requiring supervisor approval

OSHA 29 CFR 1910.1200(g)(8) requires that SDSs be readily accessible to employees during each work shift when they are in their work area. "Readily accessible" means employees can obtain the SDS immediately in an emergency — electronic SDS systems are acceptable only if employees can access them immediately without barriers, with backup provisions if the electronic system is down. SDSs must cover all hazardous chemicals in the work area.

82. Correct Answer: D — Annual releases of listed toxic chemicals to air, water, and land above reporting thresholds — enabling communities to understand chemical releases in their area

The TRI program (EPCRA Section 313) requires facilities in certain Standard Industrial Classification codes that manufacture, process, or otherwise use listed toxic chemicals above threshold quantities to submit annual Form R reports to the EPA. These reports document releases to air (stack and fugitive), water (direct discharges and stormwater), and land (landfill disposal), as well as off-site transfers. The EPA publishes TRI data publicly — it is the basis for community right-to-know about environmental releases.

83. Correct Answer: A — TSCA (Toxic Substances Control Act) — 40 CFR Part 761 — which regulates PCB use, storage, disposal, and cleanup with specific concentration-based requirements

PCBs in electrical equipment are regulated under TSCA Section 6(e), not RCRA, because PCBs were specifically addressed in TSCA legislation. 40 CFR Part 761 requires: annual inspections of PCB transformers, quarterly inspections in or near commercial buildings, spill cleanup to specific soil/surface concentration standards, manifested disposal through EPA-approved disposal facilities, and notification to fire departments for PCB transformers in or near buildings. Transformers with ≥500 ppm PCBs are regulated as PCB transformers.

84. Correct Answer: A — Automatic sprinkler systems throughout the entire building — requiring full sprinklerization of pre-law buildings above 100 feet in height

NYC Local Law 26 of 2004 requires existing high-rise office buildings (over 100 feet) to be fully sprinklered by July 1, 2019. This landmark law addressed the fire safety vulnerability of older high-rise buildings constructed before sprinkler requirements, following lessons learned from the 1 Meridian Plaza and other high-rise fires. The law required building owners to install complete NFPA 13 sprinkler systems throughout the entire building over a 15-year compliance period.

85. Correct Answer: C — Serious health hazards including carcinogenicity, respiratory sensitization, reproductive toxicity, target organ toxicity (STOT), aspiration hazard, or germ cell mutagenicity

The GHS health hazard pictogram (person silhouette with starburst) indicates Category 1 or 2 serious health hazards that may not be immediately obvious: carcinogens, respiratory sensitizers, reproductive toxins, specific target organ toxicants (STOT), aspiration hazards, and germ cell mutagens. This pictogram differs from the skull and crossbones (acute severe toxicity Categories 1–3) and the exclamation mark (less severe acute effects). Chemicals carrying this pictogram require careful long-term exposure management.

86. Correct Answer: D — 10 tons per year or more of any single HAP, or 25 tons per year or more of any combination of HAPs

Clean Air Act Section 112 defines major sources for HAPs as facilities emitting 10 tons per year (tpy) or more of any single HAP listed under Section 112(b), or 25 tpy or more of any combination of HAPs. Major sources are subject to Maximum Achievable Control Technology (MACT) standards — the most stringent emission controls achievable in practice. Area sources (below major source thresholds) may be subject to Generally Achievable Control Technology (GACT) standards.

87. Correct Answer: A — Facilitate and organize employer and employee actions during workplace emergencies — including evacuation procedures, emergency escape routes, procedures for employees who remain to perform critical operations, and accounting for all employees after evacuation

OSHA 29 CFR 1910.38 requires employers with more than 10 employees to have a written EAP covering: emergency escape procedures and routes, procedures for employees performing critical plant operations during evacuation, procedures for accounting for all employees after evacuation, rescue and medical duties, preferred means for reporting fires and emergencies, and names and contact information for persons who can be contacted for further information. The EAP must be reviewed with each employee when initially assigned and when the plan changes.

88. Correct Answer: B — Is managed under the used oil management standards — which allow recycling and burning for energy recovery under less stringent requirements than hazardous waste, provided it is not mixed with listed hazardous waste

EPA's used oil management standards (40 CFR Part 279) create a separate regulatory framework for used oil that encourages recycling and energy recovery. Used oil that is recycled or burned for energy recovery is NOT classified as hazardous waste — even though it contains hazardous constituents — as long as it has not been mixed with listed hazardous wastes and is not mixed with materials that cause it to fail hazardous waste characteristic tests (ignitability, corrosivity, reactivity, toxicity) at levels above regulatory thresholds.

89. Correct Answer: C — Standardize hazard classification criteria and communication elements (labels and SDSs) across countries — ensuring consistent information about chemical hazards worldwide

The GHS was developed by the United Nations to address the problem of different countries using incompatible hazard classification systems — the same chemical could be classified as hazardous in one country but not in another. GHS provides standardized classification criteria, label elements (pictograms, signal words, hazard statements, precautionary statements), and SDS format (16 sections) that countries adopt into their national regulations. OSHA's HazCom 2012 standard aligned the US system with GHS.

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

90. Correct Answer: C — Provide a workplace free from recognized hazards that are causing or likely to cause death or serious physical harm to employees — even when no specific OSHA standard applies to the hazard

The General Duty Clause is OSHA's "catch-all" provision — it applies whenever a recognized hazard exists that no specific OSHA standard addresses. To cite the General Duty Clause, OSHA must show: (1) the employer failed to keep the workplace free of a hazard, (2) the hazard was recognized by the employer or industry, (3) the hazard caused or was likely to cause death or serious physical harm, and (4) a feasible means existed to eliminate or materially reduce the hazard.

91. Correct Answer: A — The distance from the arc source at which the incident energy equals 1.2 cal/cm² — the onset of a second-degree burn on unprotected skin — establishing the outer boundary where arc flash PPE is required

NFPA 70E defines the arc flash protection boundary (AFB) as the distance at which incident energy equals 1.2 cal/cm² — the threshold for a curable (second-degree) burn on bare skin. Beyond the AFB, unprotected skin would not receive a second-degree burn from an arc flash event. Within the AFB, arc-rated PPE with an arc rating equal to or greater than the calculated incident energy must be worn. The AFB can range from inches to many feet depending on the available fault current and clearing time.

92. Correct Answer: C — Manually operated disconnect switches, circuit breakers, line valves, blocks, and similar devices — but NOT push buttons, selector switches, or other control circuit devices

OSHA 1910.147 defines energy isolating devices as mechanical devices that physically prevent the transmission or release of energy — including manually operated electrical circuit breakers, disconnect switches, line valves, blocks, and similar devices. Control circuit devices (push buttons, selector switches, interlocks) are specifically excluded because they do not physically interrupt the energy source — they only interrupt the control signal. Only hardware that physically isolates the energy source may be locked out.

93. Correct Answer: B — Testing the instrument on a known energized source before and after testing the circuit being worked on — the "test-before-touch" live-dead-live procedure confirming the tester works correctly

NFPA 70E Section 120.5(8) requires verification of absence of voltage using a properly rated voltage tester. The live-dead-live procedure: (1) test on a known energized source to verify the tester functions — if it doesn't read voltage on a live source, it is defective; (2) test the circuit to be worked on to verify it is de-energized; (3) test on the known energized source again to verify the tester still functions after the de-energized test. This prevents the tragic error of working on an energized circuit with a failed tester that reads zero on everything.

94. Correct Answer: C — The working space around electrical equipment must be sufficiently illuminated — NEC does not specify a lux value but requires adequate lighting; OSHA 1910.303 and building codes typically specify 50 lux (5 fc) minimum

NEC 110.26(D) states that illumination shall be provided for all working spaces about service equipment, switchboards, switchgear, panelboards, or motor control centers installed indoors — but does not specify a footcandle level. OSHA 1910.303(g)(1)(i) requires sufficient illumination for safe working conditions. OSHA Table D-3 (1910.303) and IES (Illuminating Engineering Society) standards typically specify a minimum of 50 lux (approximately 5 footcandles) for electrical equipment rooms, with higher levels recommended for detailed work. Inadequate lighting is a contributing factor in many electrical accidents.

95. Correct Answer: D — A self-contained breathing apparatus (SCBA) or supplied-air respirator operating in pressure-demand mode — the only acceptable protection above IDLH concentrations

OSHA 1910.134(d)(2) requires that in IDLH (Immediately Dangerous to Life or Health) atmospheres, only a full-facepiece SCBA certified by NIOSH operating in pressure-demand mode, or a combination full-facepiece supplied-air respirator with an auxiliary escape SCBA, is acceptable. For chlorine, IDLH is 10 ppm. Air-purifying respirators — even with acid gas cartridges — are prohibited above IDLH because cartridge breakthrough can occur instantly and the worker would have no warning before receiving a lethal dose.

96. Correct Answer: B — De-energize the circuit using the nearest disconnect or breaker before touching the victim — touching a victim still in contact with an energized source will electrocute the responder

Electrical rescue requires that the circuit be de-energized before any physical contact with the victim. Muscle tetanus caused by electrical current through the body may cause the victim to grip the energized conductor — they cannot release it voluntarily. A responder who grabs the victim without de-energizing will become a second victim. Only after confirmed de-energization should the responder approach, begin CPR if needed, and call for emergency medical services. Every second counts for cardiac arrest survival, but responder safety is the absolute first priority.

97. Correct Answer: D — Identify hazards associated with each step of a job task before work begins — allowing controls to be implemented to eliminate or reduce each hazard to an acceptable level

A Job Hazard Analysis (JHA), also called a Job Safety Analysis (JSA), breaks a task into sequential steps, identifies the hazards at each step, and specifies the controls (elimination, substitution, engineering controls, administrative controls, or PPE) to address each hazard. JHAs are completed before the task begins — not after. They involve the workers who perform the task (who often know the hazards best), and they serve as the basis for pre-task safety briefings, ensuring every team member understands what could go wrong and how to prevent it.

98. Correct Answer: A — De-energizing creates a greater hazard, is infeasible due to equipment design or operational limitations, or is required by documented necessity — and a written energized electrical work permit is issued

NFPA 70E Section 130.2(A) establishes that energized electrical work is only justified under three conditions: (1) de-energizing introduces additional hazards (e.g., loss of life support equipment, loss of illumination in a hazardous area); (2) it is infeasible due to equipment design or operational limitations (continuous process that cannot be interrupted); or (3) it is performed under an exception in the standard. In all cases, a written energized electrical work permit documenting the justification, hazard analysis, and required PPE must be completed and authorized before the work begins.

99. Correct Answer: C — Prevent the cell door from being opened unless the circuit breaker is in the fully racked-out (disconnected) and open position — and prevent the breaker from being racked in unless the door is closed

Medium-voltage switchgear safety interlocks enforce a mandatory sequence of operations that prevents simultaneous exposure to the energized bus and the accessible compartment. The door-breaker interlock prevents opening the cell door with the breaker racked in and closed — protecting against accidental contact with energized primary bus components. The rack-in interlock prevents inserting the breaker into the closed position with the door open — preventing accidental energization with the worker's hands near the primary contacts. These interlocks are required by IEEE C37.20.2 and are critical safety features of switchgear design.

100. Correct Answer: B — Receive facility-specific training on the switchgear, review the facility's switching procedures and one-line diagram, be qualified per NFPA 70E for the voltage level involved, and perform switching only under the authorization of a documented switching order — never improvise switching sequences on medium-voltage equipment

Medium-voltage switching is one of the highest-risk activities in facility operations — incorrect switching sequences can create unintended backfeeds, expose workers to energized equipment, de-energize critical loads without warning, or create out-of-phase reclosing conditions that damage equipment. Switching orders (documented, step-by-step sequences reviewed and authorized by a qualified supervisor) are mandatory in utility and industrial practice. A new engineer must be specifically trained on the facility's equipment and procedures, verified as qualified for the voltage level, and must never perform switching based on general knowledge alone — familiarity with one facility's switchgear does not automatically qualify a worker for another facility's equipment.