

PRACTICE EXAM 11: FE ELECTRICAL AND COMPUTER SIMULATION (110 QUESTIONS)

Time allotted: 5 hours 20 minutes

Materials: NCEES-approved calculator + NCEES FE Reference Handbook only

1. A 4×4 matrix has exactly two of its four rows linearly dependent (one row is a scalar multiple of another). Without further information, the rank of this matrix is:

- A. Exactly 2
- B. Exactly 4
- C. At most 3
- D. 0

2. For the function $f(x, y) = x^3 \cdot y^2 + e^{(xy)}$, evaluate $\partial f / \partial x$ at the point $(1, 2)$.

- A. 14
- B. $12 + 2 \cdot e^2$
- C. $3 + 2 \cdot e^2$
- D. $e^2 + 4$

3. Find the appropriate form of the particular solution for the ODE $y'' + 4y = 3 \cdot \cos(2t)$.

A. $y_p = A \cdot \cos(2t) + B \cdot \sin(2t)$

B. $y_p = A \cdot e^{(2t)}$

C. $y_p = A + B \cdot t$

D. $y_p = t \cdot [A \cdot \cos(2t) + B \cdot \sin(2t)]$

4. Simplify $(3 + j4) / (1 + j2)$ into standard rectangular form $a + jb$.

A. $11/5 - j2/5$

B. $11/5 + j2/5$

C. $-11/5 + j2/5$

D. $5/11 - j2/11$

5. What is the sum of the infinite geometric series $4 + 2 + 1 + 0.5 + 0.25 + \dots$?

A. 4

B. 8

C. Diverges to infinity

D. 16

6. Find the inverse Laplace transform of $F(s) = 2 / (s^2 + 9)$.

A. $2 \cdot \cos(3t)$

B. $(2/9) \cdot \sin(9t)$

C. $(2/3) \cdot \sin(3t)$

D. $2 \cdot e^{(-3t)}$

7. How many distinct binary sequences of length 8 contain exactly three 1s?

- A. 56
- B. 64
- C. 28
- D. 24

8. Evaluate the improper integral $\int_1^{\infty} (1/x^2) dx$.

- A. 0
- B. ∞ (diverges)
- C. 2
- D. 1

9. For the conservative vector field $F = \nabla(x^2 \cdot y)$, compute the line integral $\int F \cdot dr$ along any smooth path from $(0, 0)$ to $(1, 1)$.

- A. 0
- B. 2
- C. 1
- D. $1/2$

10. If $\sin \theta + \cos \theta = \sqrt{2}$, what is the value of $\sin(2\theta)$?

- A. 0
- B. 1
- C. $\sqrt{2}$
- D. $1/2$

11. Find the eigenvalues of the matrix $A = \begin{bmatrix} 3 & 1 \\ 0 & 2 \end{bmatrix}$.

- A. 3 and 0
- B. 1 and 2
- C. 5 and 0
- D. 3 and 2

12. Evaluate the limit $\lim_{x \rightarrow 0} [\sin(3x) / (2x)]$.

- A. $3/2$
- B. 0
- C. 3
- D. ∞ (the limit does not exist)

13. For an exponential distribution with rate parameter $\lambda = 2$, what is the probability density function value at $x = 1$?

- A. $2 \cdot e^{-1}$
- B. $2 - e^{-2}$
- C. $2 \cdot e^{-2}$
- D. e^{-2}

14. In a standard normal distribution $N(0, 1)$, approximately what percentage of values lies within ± 2 standard deviations of the mean?

- A. 68%
- B. 95%
- C. 99.7%
- D. 50%

15. In statistical hypothesis testing, a Type II error occurs when:

- A. The null hypothesis is rejected when it is actually true
- B. The null hypothesis is not rejected when it is actually false
- C. The alternative hypothesis is incorrectly specified
- D. The sample size is below the recommended minimum

16. Two events A and B are independent, with $P(A) = 0.3$ and $P(B) = 0.5$. What is $P(A \cup B)$?

- A. 0.80
- B. 0.15
- C. 0.50
- D. 0.65

17. The Central Limit Theorem implies that for large sample size n , the sampling distribution of the sample mean is approximately:

- A. Uniform, regardless of the underlying distribution
- B. The same as the underlying distribution
- C. Normal with mean μ and standard deviation σ/\sqrt{n}
- D. Exponential with rate parameter $1/\sigma$

18. An engineer is asked by their employer to provide a professional opinion on a topic outside their established area of expertise. According to the NSPE Code of Ethics, the engineer should:

- A. Decline the assignment or recommend a qualified specialist
- B. Accept the assignment to gain new experience through self-study
- C. Subcontract the work to multiple consulting firms simultaneously
- D. Provide preliminary opinions with appropriate disclaimers attached

19. An engineer working on a major infrastructure project discovers a design flaw that could compromise public safety, but the project is nearly complete and reporting would cause significant cost and delay. Per the NSPE Code, the engineer should:

- A. Suggest a workaround that minimizes the cost impact to the client
- B. Wait until project completion to report the issue retrospectively
- C. Notify only the immediate supervisor and consider the matter resolved
- D. Report the safety concern immediately to appropriate authorities, regardless of cost

20. An engineer is offered a high-value gift from a vendor whose products are currently being evaluated for procurement. The most ethical action is to:

- A. Accept the gift if its monetary value appears reasonable
- B. Decline the gift to avoid the appearance of conflict of interest
- C. Accept the gift but disclose it formally to management
- D. Negotiate for a different gift of equivalent monetary value

21. An engineer's professional report includes only data favorable to the client's position, omitting contradictory measurements that were taken during the same investigation. This practice is:

- A. A violation of the NSPE requirement for objective and truthful reporting
- B. Acceptable since the engineer is representing the client's interests
- C. Permissible provided the omitted data is judged non-essential
- D. Standard industry practice for advocacy-oriented engineering reports

22. A \$20,000 investment earns 8% interest compounded monthly. The effective annual interest rate is:

- A. 8.00%
- B. 7.72%
- C. 8.16%

D. 8.30%

23. In present-worth analysis, the discount rate represents:

- A. The historical inflation rate over the analysis period
- B. The bank's prevailing lending rate for the borrower
- C. The opportunity cost (rate of return available on alternative investments)
- D. The risk-free Treasury bond rate for matching maturity

24. A capital project has cash flows: $-\$50,000$ in Year 0, then $+\$15,000$ annually in Years 1 through 4. The simple payback period is:

- A. 5.0 years
- B. 3.33 years
- C. 4.0 years
- D. 2.5 years

25. When comparing two engineering alternatives by present-worth analysis with unequal service lives, the appropriate analysis period is:

- A. The shorter of the two service lives
- B. The longer of the two service lives
- C. Determined by the MARR value only
- D. A common multiple of the lives (or assume indefinite repetition)

26. In engineering economy analysis, sunk costs are:

- A. Not relevant to future decisions and should be excluded from the analysis
- B. Always amortized over the remaining project life

- C. Added to the project's net present worth as a benefit
- D. Equivalent to opportunity costs in the alternative ranking

27. The energy gap (band gap) of intrinsic silicon at room temperature is approximately:

- A. 0.66 eV
- B. 1.12 eV
- C. 3.0 eV
- D. 5.5 eV

28. In a metallic conductor, the electrical resistivity typically increases with temperature because:

- A. The free-carrier density decreases as temperature rises
- B. Electrons gradually lose their net charge above 300 K
- C. Lattice vibrations (phonons) scatter conduction electrons more frequently
- D. The metal undergoes a structural phase change near room temperature

29. For a dielectric used in a capacitor, the relative permittivity (dielectric constant) describes:

- A. The maximum leakage current the dielectric can sustain
- B. The factor by which the material increases capacitance compared to vacuum
- C. The breakdown voltage divided by the dielectric thickness
- D. The temperature coefficient of capacitance per kelvin

30. Conventional high-temperature superconductors (such as YBCO) typically transition into the superconducting state below temperatures of approximately:

- A. 4 K (liquid helium)
- B. 20 K (lower-T_c compounds)

- C. Above 300 K (room temperature)
- D. 90 K (above the liquid-nitrogen boiling point)

31. Three branches meet at a node carrying current I_1 entering the node and currents I_2 and I_3 leaving the node. Kirchhoff's Current Law (KCL) requires:

- A. $I_1 = I_2 + I_3$
- B. $I_1 + I_2 + I_3 = 0$ (all defined the same direction)
- C. $I_1 = I_2 - I_3$
- D. $I_1 \cdot I_2 = I_3$

32. A $10 \mu\text{F}$ capacitor is charged to 50 V. The total charge stored is:

- A. 0.05 mC
- B. 5 mC
- C. 0.5 mC
- D. 50 mC

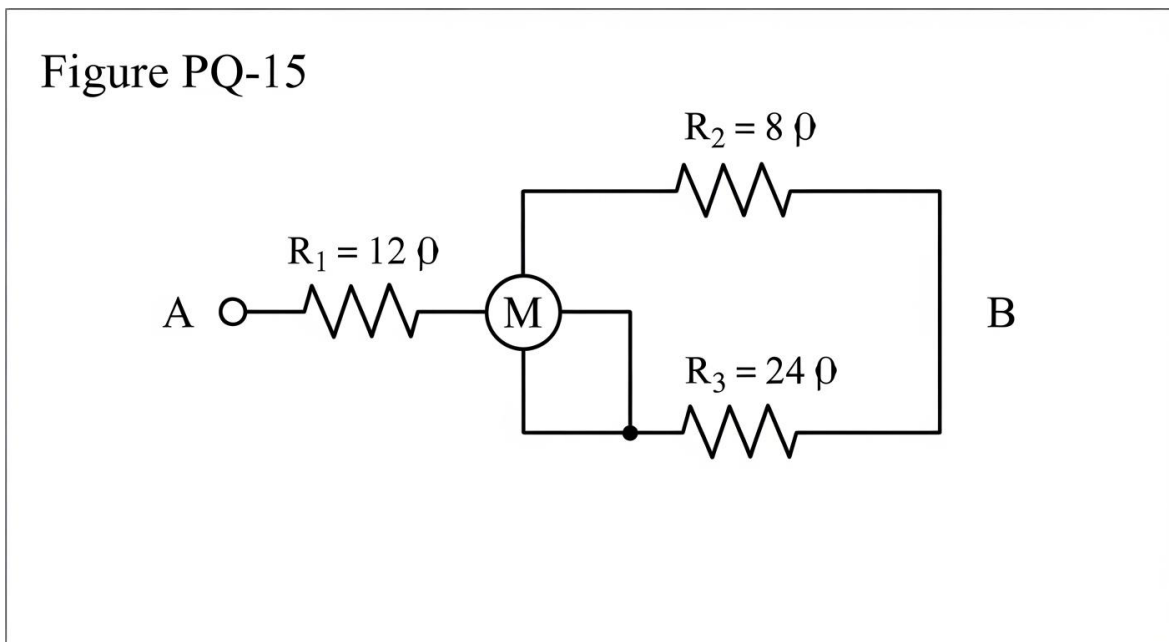
33. A series RC circuit with $R = 1 \text{ k}\Omega$ and $C = 1 \mu\text{F}$ is connected to a 10 V DC source through an initially open switch. After the switch closes (with the capacitor initially uncharged), the voltage across the capacitor at $t = 1 \text{ ms}$ is approximately:

- A. 0 V
- B. 6.32 V
- C. 3.68 V
- D. 10 V

34. In a 60 Hz AC circuit, the inductive reactance of an inductor with $L = 100 \text{ mH}$ is:

- A. 6.0Ω
- B. 60Ω
- C. 16.67Ω
- D. 37.7Ω

35. For the resistor network shown in the figure, what is the equivalent resistance measured between terminals A and B?



- A. 18Ω
- B. 12Ω
- C. 8Ω
- D. 32Ω

36. A parallel RLC circuit has $R = 10 \Omega$, $L = 5 \text{ mH}$, and $C = 100 \mu\text{F}$. The undamped resonant angular frequency ω_0 is:

- A. 100 rad/s
- B. $5,000 \text{ rad/s}$

- C. 707 rad/s
- D. 1,414 rad/s

37. For a sinusoidal source voltage $v(t) = 170 \cdot \cos(377t)$ V, the RMS value is approximately:

- A. 170 V
- B. 85 V
- C. 120 V
- D. 240 V

38. A circuit contains two independent voltage loops with no shared element except the source. The most direct method to solve for all branch currents is:

- A. Apply Ohm's law to each resistor individually
- B. Use mesh analysis (assign mesh currents and solve the linear system)
- C. Apply the superposition principle to voltage sources only
- D. Set up power-balance equations for each loop

39. A series RL circuit has $R = 10 \Omega$ and $L = 100$ mH and is driven at 60 Hz. The phase angle by which the source voltage leads the current is:

- A. 0°
- B. 45°
- C. 75.1°
- D. 90°

40. A Thevenin equivalent circuit has $V_{TH} = 20$ V and $R_{TH} = 5 \Omega$. The maximum power that can be delivered to a resistive load is:

- A. 20 W
- B. 80 W
- C. 5 W
- D. 100 W

41. A sinusoidal current $I = 10\angle 30^\circ$ A (rms) flows through an impedance $Z = 5\angle 45^\circ \Omega$. The voltage across Z in polar form is:

- A. $50\angle 15^\circ$ V
- B. $50\angle 75^\circ$ V
- C. $50\angle 45^\circ$ V
- D. $50\angle -15^\circ$ V

42. Applying a source transformation to a circuit element converts between:

- A. Dependent and independent source forms
- B. Series and parallel arrangements automatically
- C. Discrete and continuous-time representations
- D. Thevenin (voltage source + series resistance) and Norton (current source + parallel resistance) equivalents

43. Two impedances $Z_1 = 4 + j3 \Omega$ and $Z_2 = 6 - j8 \Omega$ are connected in series across a sinusoidal source. The magnitude of the total impedance is:

- A. 11.18Ω
- B. 10Ω
- C. 14.14Ω
- D. 25Ω

44. For a continuous-time LTI system, the impulse response $h(t)$ and the frequency response $H(j\omega)$ are related by:

- A. Differentiation in time
- B. The z-transform operator
- C. The Fourier transform: $H(j\omega) = \int h(t) \cdot e^{(-j\omega t)} dt$
- D. Convolution with the unit step function

45. A system characterized by the input-output relationship $y(t) = 5 \cdot x(t) + 3$ is:

- A. Linear but time-varying because of the multiplier
- B. Nonlinear because of the constant offset term
- C. Linear and time-invariant
- D. Not a valid system at all

46. For an LTI system with transfer function $H(s) = (s + 1)/(s^2 + 2s + 5)$, the steady-state response to a unit step input is:

- A. $1/5$ (the DC gain $H(0)$)
- B. 1
- C. 0
- D. ∞ (the system is unstable)

47. For a discrete-time LTI system with input $x[n] = \delta[n]$ producing output $y[n] = h[n]$, the system is fully characterized by:

- A. The DC gain alone
- B. A constant input-to-output time delay only
- C. The memory length of the system in samples
- D. The impulse response $h[n]$

48. The Laplace transform pair $L\{\cos(\omega t) \cdot u(t)\} = s/(s^2 + \omega^2)$ is most useful for analyzing:

- A. Pure exponential decay processes
- B. Steady-state DC behavior of circuits
- C. Sinusoidal transient and steady-state responses
- D. Stability of nonlinear feedback systems

49. The frequency response of an ideal integrator $H(s) = 1/s$ exhibits:

- A. Constant magnitude with linearly varying phase
- B. Magnitude $|H(j\omega)| = 1/\omega$ with phase $= -90^\circ$
- C. Magnitude $|H(j\omega)| = \omega$ with phase $= +90^\circ$
- D. A bandpass-filter magnitude shape

50. The Nyquist-Shannon sampling theorem requires that the sampling rate for distortionless reconstruction be:

- A. Equal to the maximum frequency of the signal
- B. Less than the total signal bandwidth
- C. Higher than the half-bandwidth of the signal
- D. At least twice the highest frequency component in the signal

51. An analog signal is sampled at 8 kHz. According to the Nyquist criterion, the maximum signal frequency that can be reconstructed without aliasing is:

- A. 4 kHz
- B. 8 kHz
- C. 16 kHz
- D. 2 kHz

52. The Fast Fourier Transform (FFT) algorithm reduces the computational complexity of an N-point DFT from $O(N^2)$ to:

- A. $O(N)$
- B. $O(\log N)$
- C. $O(N \cdot \log N)$
- D. $O(N^3)$

53. A digital filter is described by the difference equation $y[n] = x[n] - x[n - 1]$. This filter functions as:

- A. A low-pass FIR averaging filter
- B. A high-pass first-difference FIR filter
- C. An IIR all-pass filter
- D. A bandstop notch filter

54. A continuous-time signal $x(t) = 3 \cdot \sin(2\pi \cdot 100t) + 2 \cdot \sin(2\pi \cdot 300t)$ is to be digitally sampled. The minimum sampling frequency to avoid aliasing is:

- A. 100 Hz
- B. 300 Hz
- C. 500 Hz
- D. 600 Hz

55. For a wide-sense stationary random signal, the autocorrelation function evaluated at lag zero $R_{xx}(0)$ equals:

- A. The signal mean value
- B. The signal variance only (excluding the DC component)
- C. Zero in all cases

D. The mean-square value (average power) of the signal

56. For a forward-biased silicon p-n junction diode at room temperature, the typical voltage drop across the junction is approximately:

- A. 0.0 V (no drop in the ideal case)
- B. 0.3 V (germanium diodes)
- C. 0.6 to 0.7 V
- D. 2.0 V (typical LED forward voltage)

57. In a common-source NMOS small-signal amplifier with drain resistor R_D and an ideal source, the voltage gain is approximately:

- A. $+R_D / R_S$
- B. $-g_m \cdot R_D$
- C. $+\beta \cdot R_D$
- D. $R_D \cdot V_{DD}$

58. A BJT operates in the active (forward) region when:

- A. The base-emitter junction is forward-biased AND the base-collector junction is reverse-biased
- B. Both p-n junctions are forward-biased simultaneously
- C. Both p-n junctions are reverse-biased simultaneously
- D. The base current is exactly zero (cutoff)

59. In a non-inverting op-amp amplifier with $R_f = 90 \text{ k}\Omega$ in the feedback path and $R_1 = 10 \text{ k}\Omega$ from the inverting input to ground, the closed-loop voltage gain is:

- A. 9

- B. -9
- C. 10
- D. -10

60. For a JFET operating in the saturation (pinch-off) region, the drain current I_D depends primarily on:

- A. The gate-source voltage V_{GS} (square-law dependence on $V_{GS} - V_P$)
- B. The drain-source voltage V_{DS} in a strong, linear manner
- C. The gate-drain capacitance C_{GD}
- D. The drain temperature alone

61. A precision Zener voltage reference circuit produces the most stable output voltage when:

- A. The Zener is operated at very low current near the knee of the I-V curve
- B. The Zener current is held nearly constant within its specified operating range
- C. The Zener is biased into avalanche breakdown only at the highest specified voltage
- D. Multiple Zener diodes are connected in parallel for current averaging

62. In an op-amp differential input stage, the common-mode rejection ratio (CMRR) is defined as:

- A. The ratio of input signal voltage to output signal voltage
- B. The maximum allowable input voltage swing
- C. The ratio of differential-mode gain to common-mode gain, typically expressed in dB
- D. The supply voltage divided by the input offset voltage

63. In a static (unswitching) CMOS digital inverter, the dominant component of power dissipation is:

- A. Resistive losses within the transistor channel

- B. Transient currents that flow during switching events
- C. DC bias current drawn continuously from the supply
- D. Subthreshold leakage currents through both transistors

64. A balanced three-phase Y-connected load is supplied with a line-to-line voltage of 400 V (rms). The line-to-neutral (phase) voltage is approximately:

- A. 231 V
- B. 400 V
- C. 692 V
- D. 200 V

65. In a single-phase AC system, the real power P , reactive power Q , and apparent power S are related by:

- A. $S = P - Q$
- B. $S^2 = P^2 + Q^2$
- C. $P = S + Q$
- D. $S = \sqrt{(P + Q)}$

66. A three-phase induction motor operates with a slip of 3% at full load. If the synchronous speed is 1,800 rpm, the actual rotor speed is:

- A. 1,800 rpm
- B. 60 rpm
- C. 1,854 rpm
- D. 1,746 rpm

67. A power transformer's full-load efficiency is typically maximized when:

- A. The copper (I^2R) losses equal the core (iron) losses
- B. Core losses are about 10 times the copper losses
- C. The load current is reduced to the no-load condition
- D. The supply frequency is doubled above the design value

68. In a 60 Hz, three-phase, four-pole synchronous generator operating at synchronous speed, the rotor mechanical rotational frequency is:

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

69. Power-factor correction in industrial loads is most commonly achieved by:

- A. Increasing the physical size of the motors
- B. Connecting capacitor banks in parallel with the load
- C. Reducing the supply voltage
- D. Switching from three-phase to single-phase service

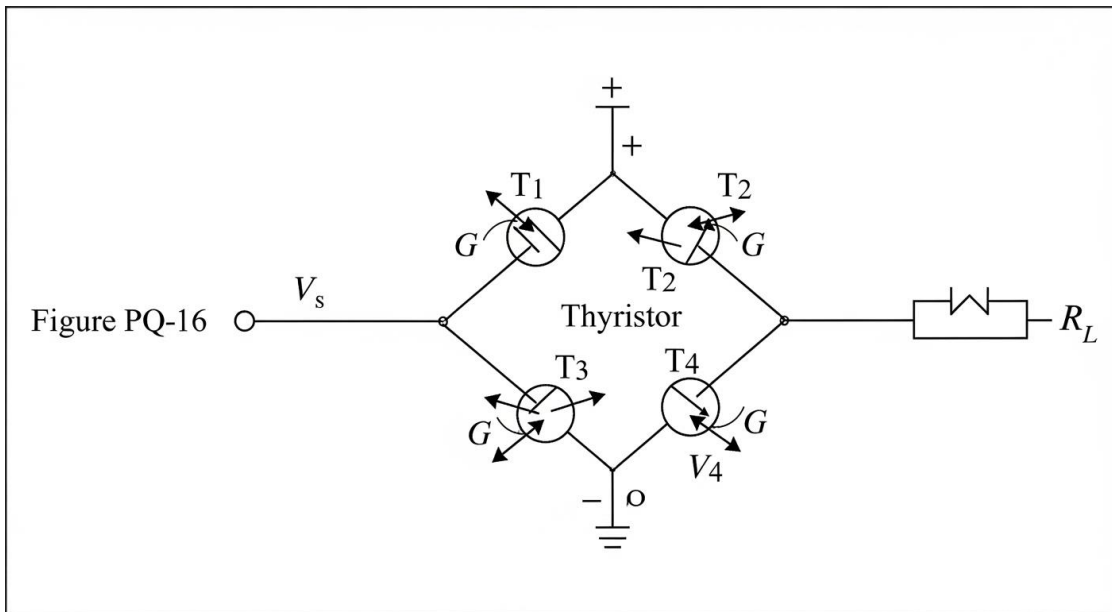
70. For a 13.8 kV (line-to-line) distribution circuit analyzed in per-unit with a voltage base of 13.8 kV, the per-unit voltage of the system at rated conditions is:

- A. 0.1
- B. 13.8
- C. 138
- D. 1.0

71. In a DC machine, the field winding establishes the main magnetic flux, while the armature winding carries:

- A. Only the field current itself
- B. No appreciable current under normal load conditions
- C. The load (working) current that interacts with the magnetic flux to produce torque or EMF
- D. Only alternating current produced by the commutator

72. A line-commutated full-wave thyristor rectifier supplying a resistive load is shown in the figure. To reduce the average DC output voltage from its maximum value, the operator should:



- A. Increase the thyristor firing angle α (delay the firing relative to the zero-crossing)
- B. Decrease the source frequency to a lower value
- C. Decrease the number of thyristors in the bridge configuration
- D. Install a step-down transformer between the source and the bridge

73. Gauss's Law for electric fields states that the total electric flux through any closed surface equals:

- A. Zero for any closed surface regardless of enclosed charge

- B. The total enclosed charge divided by ϵ_0
- C. The electric field magnitude times the total surface area
- D. The voltage measured anywhere on the closed surface

74. A point charge of $1 \mu\text{C}$ is placed in free space. The magnitude of the electric field at a distance of 1 m from the charge is:

- A. 9 V/m
- B. 9×10^6 V/m
- C. 9×10^{12} V/m
- D. 9×10^3 V/m

75. The characteristic impedance of a coaxial transmission line depends primarily on:

- A. The total length of the cable only
- B. The operating frequency only
- C. The ratio of outer-to-inner conductor radii and the dielectric permittivity
- D. The conductor temperature alone

76. For a plane electromagnetic wave propagating in free space, the intrinsic impedance (ratio of E-field to H-field) is approximately:

- A. 377Ω
- B. 50Ω
- C. 75Ω
- D. 0Ω

77. The settling time of an underdamped second-order control system, using the 2% criterion, is approximately:

- A. $1 / \omega_n$
- B. $\pi / (\zeta \cdot \omega_n)$
- C. $1 / (\zeta \cdot \omega_n)$
- D. $4 / (\zeta \cdot \omega_n)$

78. In a PID controller with transfer function $K_p + K_i/s + K_d \cdot s$, the proportional gain K_p primarily affects:

- A. The complete elimination of long-term steady-state offset
- B. The system response speed and reduction of steady-state error
- C. Disturbance rejection at low frequencies only
- D. The high-frequency noise sensitivity of the loop exclusively

79. A closed-loop control system has the characteristic equation $s^3 + 5s^2 + 8s + 6 = 0$. Applying the Routh-Hurwitz criterion confirms that:

- A. The system has poles in the right-half s-plane (unstable)
- B. The system has poles exactly on the imaginary axis (marginally stable)
- C. The system is stable (all coefficients positive AND the first column of the Routh array is positive)
- D. The system has a pole at the origin

80. For a unity-feedback system with forward path $G(s) = 10/(s + 2)$, the closed-loop transfer function $T(s) = Y(s)/R(s)$ is:

- A. $10 / (s + 12)$
- B. $10 / (s + 2)$
- C. $1 / (s + 2)$
- D. $10 / (s^2 + 12)$

81. In root-locus analysis as the loop gain K increases from 0 to ∞ , the branches of the locus terminate at:

- A. Points where the system's gain margin equals zero
- B. The open-loop poles (where they originate)
- C. Infinity only, regardless of zero locations
- D. The open-loop zeros (finite zeros if they exist, otherwise infinity)

82. In Bode-plot stability analysis, the phase margin is measured at the frequency where:

- A. The phase shift of $G(j\omega)$ equals -180°
- B. The magnitude $|G(j\omega)|$ crosses unity (0 dB)
- C. The gain margin happens to equal zero
- D. The Nyquist contour encircles the -1 point

83. In a continuous-time PI controller, the role of the integral term is primarily to:

- A. Add high-frequency noise to the control signal
- B. Increase the magnitude of the dominant closed-loop pole
- C. Eliminate steady-state error to step inputs by accumulating past error
- D. Cause sustained oscillation in all closed-loop systems

84. Single-sideband (SSB) modulation differs from double-sideband (DSB) modulation in that:

- A. SSB transmits only one of the two sidebands, halving the required bandwidth
- B. SSB uses a different carrier frequency than DSB
- C. SSB requires substantially more transmit power for the same coverage
- D. SSB is incompatible with synchronous (coherent) demodulation

85. In a 4-PSK (QPSK) digital modulation system, each transmitted symbol carries:

- A. 1 bit of information
- B. 4 bits of information
- C. 8 bits of information
- D. 2 bits of information

86. Shannon's channel capacity for a band-limited AWGN channel with bandwidth B and signal-to-noise ratio SNR is given by:

- A. $C = B \cdot SNR$
- B. $C = B \cdot \log_2(1 + SNR)$
- C. $C = SNR / B$
- D. $C = \log_2(B \cdot SNR)$

87. In a digital communication receiver operating in additive white Gaussian noise, the matched filter is the optimal linear filter for:

- A. Maximizing the signal-to-noise ratio at the sampling instant
- B. Completely eliminating intersymbol interference
- C. Reducing the transmitter's required power
- D. Increasing the carrier frequency at the receiver front end

88. Direct-sequence spread-spectrum modulation provides which key advantage compared to conventional narrowband modulation?

- A. A higher peak data rate than non-spread systems at the same SNR
- B. A reduction in required antenna gain at the receiver
- C. Improved resistance to narrowband interference and multipath effects

D. Lower DC power consumption in the transmitter circuitry

89. In the OSI reference model, the layer responsible for providing end-to-end reliable delivery between two endpoints is the:

A. Physical layer (Layer 1)

B. Data link layer (Layer 2)

C. Transport layer (Layer 4)

D. Application layer (Layer 7)

90. A TCP connection is established between client and server through the three-way handshake. The correct packet sequence is:

A. SYN → ACK → FIN

B. SYN → SYN-ACK → FIN

C. ACK → SYN → ACK

D. SYN → SYN-ACK → ACK

91. For a Category 6 (Cat6) Ethernet installation at 1 Gbps, the standard maximum cable run length is typically:

A. 50 meters

B. 100 meters

C. 200 meters

D. 1,000 meters

92. The Border Gateway Protocol (BGP) is used primarily for:

A. Inter-autonomous-system (inter-AS) routing across the Internet backbone

- B. Local Ethernet frame switching within a single subnet
- C. Wi-Fi access-point authentication of client devices
- D. Loopback interface address assignment

93. Convert the binary number $1101\ 0110_2$ to its decimal equivalent.

- A. 86
- B. 192
- C. 218
- D. 214

94. The Boolean expression $A \cdot (B + C)$ is logically equivalent to:

- A. $A \cdot B \cdot C$
- B. $A + B + C$
- C. $A \cdot B + A \cdot C$
- D. $(A + B) \cdot (A + C)$

95. A 4-to-1 digital multiplexer (MUX) requires how many binary select lines?

- A. 1
- B. 4
- C. 2
- D. 3

96. An SR latch receives the input combination $S = 1, R = 0$. The resulting output state is:

- A. $Q = 0$ (reset state)

- B. Q holds its previous value (no change)
- C. Q is indeterminate (forbidden state)
- D. Q = 1 (set state)

97. A D-type flip-flop captures the input data D into the output Q on:

- A. Both clock edges (level-sensitive behavior)
- B. The active clock edge (rising or falling, depending on the device specification)
- C. Only the asynchronous reset input transitions
- D. Continuously, as long as the clock signal is held HIGH

98. Using 8-bit two's complement representation, the range of signed integers that can be represented is:

- A. -128 to +127
- B. -127 to +127
- C. 0 to 255
- D. -255 to +255

99. The output of a purely combinational logic circuit:

- A. Depends on past inputs and internal state
- B. Depends only on the current input values (the circuit is memoryless)
- C. Always contains explicit feedback paths
- D. Requires a periodic clock signal to update

100. For an n-input AND gate, the output is HIGH (1) when:

- A. Any one of the n inputs is HIGH

- B. Exactly half of the inputs are HIGH
- C. The majority of the inputs are HIGH
- D. ALL n inputs are simultaneously HIGH

101. A 3-bit binary up-counter cycles through how many distinct states before rolling over?

- A. 8 states (0 through 7)
- B. 3 states
- C. 6 states
- D. 9 states

102. In a CPU pipeline, a structural hazard occurs when:

- A. Two instructions need to read the same register
- B. The branch predictor produces an incorrect prediction
- C. Two pipeline stages require the same physical hardware resource at the same time
- D. The pipeline currently contains no instructions to execute

103. A direct-mapped cache has 1,024 cache lines with 64 bytes per line. In partitioning a memory address into tag, index, and offset fields, the offset field requires:

- A. 64 bits
- B. 6 bits
- C. 10 bits
- D. 0 bits

104. Virtual memory in modern operating systems primarily provides:

- A. A logical address space larger than physical RAM, with paging between RAM and disk

- B. Faster CPU clock speeds via memory subsystem tuning
- C. Reduced overall power consumption of the memory subsystem
- D. Static, compile-time address assignment for all program data

105. In Amdahl's Law, the maximum achievable speedup of a program with parallelizable fraction p , running on N processors, approaches what limit as $N \rightarrow \infty$?

- A. $p \cdot N$
- B. N
- C. 1
- D. $1 / (1 - p)$

106. A defining characteristic of a Reduced Instruction Set Computer (RISC) architecture is:

- A. Variable-length instructions tuned to each opcode
- B. A wide variety of complex memory addressing modes
- C. Fixed (uniform) instruction length and simple addressing modes
- D. Hundreds of CPU registers visible to the programmer

107. In the Waterfall software development model, project phases follow:

- A. A strictly linear sequence (requirements \rightarrow design \rightarrow implementation \rightarrow testing \rightarrow maintenance)
- B. Concurrent execution of all phases throughout the project
- C. Reverse order, ending with requirements gathering
- D. An unbounded repeating cycle with no defined end state

108. In object-oriented programming, encapsulation refers to:

- A. Inheritance of attributes from a base class to a derived class

- B. Bundling data and the methods that operate on that data, with controlled (private/public) access
- C. Allowing one object to take many different forms at runtime
- D. Defining abstract base classes that cannot be instantiated directly

109. A test that verifies that individual functions or methods work correctly in isolation from the rest of the system is called:

- A. Integration testing
- B. System testing
- C. Unit testing
- D. Acceptance testing

110. In software development, the primary purpose of code review is to:

- A. Identify defects and improve code quality through peer examination before code is merged
- B. Reduce the total number of test cases that must be written for the project
- C. Replace formal testing activities entirely
- D. Standardize the formatting of code comments throughout the codebase

PRACTICE EXAM 11 – ANSWER KEY AND FULL ANSWER EXPLANATIONS

1. C — A 4×4 matrix can have maximum rank 4, but when two of its four rows are linearly dependent (one is a scalar multiple of the other), those two rows together contribute only one independent direction. The remaining two rows may or may not be independent of each other and of the first pair, so the rank is bounded above by 3 but could be lower.
2. B — Take the partial with respect to x while treating y as constant: $\partial f / \partial x = 3x^2 \cdot y^2 + y \cdot e^{(xy)}$. Substituting $(1, 2)$: $3 \cdot 1 \cdot 4 + 2 \cdot e^2 = 12 + 2 \cdot e^2$. The chain rule applied to $e^{(xy)}$ with x as the differentiation variable produces the factor y in front of the exponential.
3. D — The characteristic equation $r^2 + 4 = 0$ yields roots $r = \pm 2j$, so $\cos(2t)$ and $\sin(2t)$ already appear in the homogeneous solution. The forcing function $3 \cdot \cos(2t)$ matches a homogeneous mode,

producing resonance, so the particular solution must be multiplied by t . This treatment is the textbook rule when forcing frequency coincides with natural frequency.

4. A — Multiply numerator and denominator by the conjugate $(1 - j2)$: $[(3 + j4)(1 - j2)] / [(1 + j2)(1 - j2)] = (3 + 8 + j(-6 + 4))/5 = (11 - j2)/5 = 11/5 - j2/5$. Conjugate multiplication is the canonical technique for putting complex quotients into rectangular form.
5. B — The infinite geometric series with first term $a = 4$ and common ratio $r = 1/2$ converges because $|r| < 1$. Its sum is $S = a/(1 - r) = 4/(1 - 0.5) = 4/0.5 = 8$. Geometric series with $|r| \geq 1$ diverge.
6. C — The standard Laplace pair $L\{\sin(at) \cdot u(t)\} = a/(s^2 + a^2)$ identifies $a = 3$ from the denominator $s^2 + 9$. To match the numerator 2 rather than 3, factor as $2/(s^2 + 9) = (2/3) \cdot [3/(s^2 + 9)]$, giving the inverse transform $(2/3) \cdot \sin(3t)$. Scaling constants in the numerator simply pull out of the inverse operation.
7. A — The number of length-8 binary sequences with exactly three 1s equals the number of ways to choose three positions for the 1s from eight: $C(8, 3) = 8!/(3! \cdot 5!) = 56$. This is the standard combinatorial count of unordered position selections, with the remaining five bits forced to be 0.
8. D — Evaluate as a limit: $\int_1^\infty x^{-2} dx = \lim_{b \rightarrow \infty} [-1/x]_1^b = \lim_{b \rightarrow \infty} (-1/b + 1) = 1$. The integral converges because $1/x^2$ decays faster than $1/x$ as x grows. Such convergence behavior is characteristic of integrands with power greater than 1 in the denominator.
9. C — For a conservative field $F = \nabla f$, the line integral depends only on endpoints: $\int F \cdot dr = f(\text{end}) - f(\text{start})$. Here $f(x, y) = x^2 \cdot y$, giving $f(1, 1) - f(0, 0) = 1 - 0 = 1$. Path independence is the defining property of conservative vector fields.
10. B — Square both sides of the identity $\sin \theta + \cos \theta = \sqrt{2}$: $(\sin \theta + \cos \theta)^2 = \sin^2 \theta + 2 \cdot \sin \theta \cdot \cos \theta + \cos^2 \theta = 1 + \sin(2\theta)$. Since $(\sqrt{2})^2 = 2$, we have $2 = 1 + \sin(2\theta)$, giving $\sin(2\theta) = 1$. This identity uses the double-angle formula $2 \cdot \sin \theta \cdot \cos \theta = \sin(2\theta)$.
11. D — For an upper-triangular matrix, the eigenvalues are exactly the diagonal entries because $\det(A - \lambda I)$ reduces to the product of diagonal differences. Reading the diagonal of A directly: 3 and 2. This shortcut applies whenever the matrix is triangular (upper or lower).
12. A — Apply the small-angle approximation $\sin(3x) \approx 3x$ as $x \rightarrow 0$, giving $\sin(3x)/(2x) \rightarrow 3x/(2x) = 3/2$. L'Hôpital's rule gives the same result: $3 \cdot \cos(3x)/2 \rightarrow 3/2$. This limit is fundamental and underlies the derivative of $\sin(ax)$ at the origin.
13. C — The exponential probability density function is $f(x) = \lambda \cdot e^{-\lambda x}$ for $x \geq 0$. With $\lambda = 2$ and $x = 1$: $f(1) = 2 \cdot e^{-2}$. The exponential distribution describes memoryless waiting times in reliability and queuing analysis.
14. B — The empirical rule for the standard normal distribution states that approximately 68% of values lie within $\pm 1\sigma$, 95% within $\pm 2\sigma$, and 99.7% within $\pm 3\sigma$. The 95% figure is the basis for two-sigma confidence intervals widely used in quality control and measurement uncertainty.
15. B — A Type II error (β error) is defined as failing to reject the null hypothesis when it is actually false — missing a real effect. By contrast, a Type I error (α error) is rejecting a true null. Statistical power equals $1 - \beta$, the probability of correctly detecting a real effect.
16. D — For independent events, $P(A \cap B) = P(A) \cdot P(B) = 0.3 \cdot 0.5 = 0.15$. By inclusion-exclusion: $P(A \cup B) = P(A) + P(B) - P(A \cap B) = 0.3 + 0.5 - 0.15 = 0.65$. Independence is what enables direct multiplication for the joint probability.
17. C — The Central Limit Theorem states that the sampling distribution of the sample mean approaches a normal distribution with mean μ and standard deviation σ/\sqrt{n} as n grows, regardless of the underlying population shape. The \sqrt{n} shrinkage in the standard error explains why larger samples produce more precise estimates.

18. A — NSPE Section II.2.a requires engineers to undertake assignments only when qualified by education and experience in the relevant technical area. When asked to work outside that competency, the engineer must decline or bring in a qualified specialist. Practicing outside one's competence endangers the public and exposes the engineer to professional sanctions.
19. D — NSPE Canon 1 makes public safety, health, and welfare paramount obligations that override employer or client interests. When internal channels fail to address a safety concern, the engineer must notify appropriate authorities regardless of cost or schedule impact. This duty to the public stands above contractual loyalty.
20. B — NSPE Section II.4 requires engineers to avoid even the appearance of conflict of interest when their professional judgment could be perceived as influenced by gifts or favors from vendors. Declining is the cleanest action that preserves objectivity in an active procurement process. Disclosure alone is generally insufficient when an evaluation is underway.
21. A — NSPE Section III.3.a requires engineers to be objective and truthful in all professional reports, including disclosure of all relevant data. Selectively omitting contradictory evidence to favor a client's position violates this duty of objective reporting. The obligation to objectivity is independent of who is paying for the work.
22. D — Convert nominal annual rate to effective annual rate: $i_{\text{eff}} = (1 + i_{\text{period}})^n - 1$, where $i_{\text{period}} = 0.08/12$ and $n = 12$ compounding periods. Calculating: $(1.006667)^{12} - 1 \approx 1.0830 - 1 = 0.0830 = 8.30\%$. More frequent compounding raises the effective rate above the nominal value.
23. C — The discount rate represents the opportunity cost of capital — the rate of return achievable on the next-best alternative use of the funds at comparable risk. It captures both the time value of money and the investor's required return. The discount rate is not simply the inflation rate or any single bond yield.
24. B — Simple payback period = initial investment / annual cash flow = $\$50,000 / \$15,000 = 3.33$ years. Simple payback ignores both the time value of money and any cash flows beyond the payback point. It is widely used as a screening criterion despite its limitations.
25. D — When comparing alternatives with unequal service lives by present worth, the analysis period should be a common multiple of the individual lives (or assume indefinite repetition). This ensures fair comparison by capturing the full cycle of replacements. Using an arbitrary shorter period biases the analysis toward the alternative whose life ends sooner.
26. A — Sunk costs are past expenditures that cannot be recovered and therefore have no influence on going-forward decisions. Including them distorts the comparison of future alternatives by anchoring the analysis to irrecoverable amounts. Only incremental future cash flows are relevant in engineering economy analysis.
27. B — The energy gap of intrinsic silicon at 300 K is approximately 1.12 eV. This value sets the energy required to excite electrons from valence to conduction band and determines silicon's intrinsic carrier concentration and temperature dependence. Germanium has a smaller gap (0.66 eV) and diamond a much larger one (5.5 eV).
28. C — In a metal, carrier density is essentially temperature-independent, but lattice vibrations (phonons) grow stronger with temperature and scatter conduction electrons more frequently. This increased scattering raises resistivity nearly linearly with temperature for most metals. The positive temperature coefficient is the defining electrical signature of metallic conduction.
29. B — Relative permittivity ϵ_r is defined as the ratio of capacitance with the dielectric to the capacitance with vacuum between the same plates: $\epsilon_r = C/C_0$. Higher ϵ_r yields greater charge storage per unit voltage. This property is what makes dielectric selection critical in capacitor design.

30. D — High-temperature superconductors such as $\text{YBa}_2\text{Cu}_3\text{O}_7$ (YBCO) have critical temperatures around 90 K, above the boiling point of liquid nitrogen (77 K). This is a major practical advantage over conventional superconductors that require liquid helium cooling. Cuprate-class HTS materials reach T_c up to about 138 K at ambient pressure.
31. A — Kirchhoff's Current Law states that the algebraic sum of currents at any node is zero: currents entering equal currents leaving. With I_1 entering and I_2, I_3 leaving: $I_1 = I_2 + I_3$. KCL is the foundation of nodal circuit analysis.
32. C — The charge stored on a capacitor is $Q = C \cdot V = (10 \times 10^{-6} \text{ F}) \cdot (50 \text{ V}) = 5 \times 10^{-4} \text{ C} = 500 \text{ } \mu\text{C} = 0.5 \text{ mC}$. Charge is directly proportional to capacitance and voltage. This linear relationship is the defining behavior of an ideal capacitor.
33. B — The time constant is $\tau = RC = (1 \text{ k}\Omega)(1 \text{ } \mu\text{F}) = 1 \text{ ms}$. At $t = \tau$, the capacitor charges to $V_C = V(1 - e^{-1}) = 10 \cdot (1 - 0.368) = 6.32 \text{ V}$. The exponential rise approaches the source value asymptotically, reaching about 63.2% after one time constant.
34. D — Inductive reactance $X_L = \omega L = 2\pi \cdot f \cdot L = 2\pi \cdot 60 \cdot 0.1 \approx 37.7 \text{ } \Omega$. Reactance is the imaginary part of the impedance and scales linearly with frequency. Above 60 Hz, the inductor presents progressively greater opposition to current flow.
35. A — Combine the parallel pair first: $R_2 \parallel R_3 = (8 \cdot 24)/(8 + 24) = 192/32 = 6 \text{ } \Omega$. Then add the series element: $R_{\text{total}} = R_1 + 6 = 12 + 6 = 18 \text{ } \Omega$. Systematic reduction of parallel groups before adding series components is the standard approach for ladder networks.
36. D — The undamped resonant frequency of an LC circuit is $\omega_0 = 1/\sqrt{LC} = 1/\sqrt{(5 \times 10^{-3} \cdot 100 \times 10^{-6})} = 1/\sqrt{(5 \times 10^{-7})} \approx 1,414 \text{ rad/s}$. At this frequency, inductor and capacitor reactances cancel. Resonance is the operating principle of tuned circuits and filters.
37. C — For a sinusoid $v(t) = V_p \cdot \cos(\omega t)$, the RMS value is $V_p/\sqrt{2} = 170/1.414 \approx 120.2 \text{ V}$. This corresponds to the standard US line voltage of 120 V (RMS) with peak about 170 V. RMS values are used because they produce the same heating in a resistor as an equivalent DC voltage.
38. B — Mesh analysis assigns a clockwise current to each independent loop and applies KVL around each mesh, producing a linear system that solves directly for all branch currents. This is the most systematic method for two-loop and multi-loop circuits with voltage sources. Nodal analysis is the dual approach using KCL at each node.
39. C — Inductive reactance at 60 Hz: $X_L = 2\pi \cdot 60 \cdot 0.1 = 37.7 \text{ } \Omega$. Phase angle: $\phi = \arctan(X_L/R) = \arctan(37.7/10) \approx 75.1^\circ$. Voltage leads current in an inductive circuit by this angle, and the magnitude grows with the ratio of reactance to resistance.
40. A — Maximum power transfer requires $R_{\text{load}} = R_{\text{TH}} = 5 \text{ } \Omega$. The maximum delivered power is $P_{\text{max}} = V_{\text{TH}}^2/(4 \cdot R_{\text{TH}}) = (20)^2/(4 \cdot 5) = 400/20 = 20 \text{ W}$. The factor of 4 arises because half of V_{TH} drops across R_{TH} at the matched condition.
41. B — In phasor algebra, $V = I \cdot Z$, with magnitudes multiplied and angles added: $V = (10 \angle 30^\circ) \cdot (5 \angle 45^\circ) = 50 \angle (30^\circ + 45^\circ) = 50 \angle 75^\circ \text{ V}$. Polar-form multiplication is the standard technique for AC circuit calculations.
42. D — Source transformation converts a Thevenin form (voltage source V in series with R) to a Norton form (current source $I = V/R$ in parallel with R), and vice versa. Both forms produce identical terminal behavior. This equivalence simplifies circuit analysis when combining sources or reducing networks.
43. A — Add complex impedances component-wise: $Z_{\text{total}} = (4 + 6) + j(3 - 8) = 10 - j5 \text{ } \Omega$. Magnitude: $|Z| = \sqrt{(10^2 + 5^2)} = \sqrt{125} \approx 11.18 \text{ } \Omega$. Series impedances add directly in rectangular form regardless of whether components are resistive, inductive, or capacitive.

44. C — For an LTI system, the frequency response $H(j\omega)$ is the Fourier transform of the impulse response $h(t)$: $H(j\omega) = \int h(t) \cdot e^{-j\omega t} dt$. This relationship enables analysis either in the time domain (convolution) or the frequency domain (multiplication). It is the foundation of all linear systems theory.
45. B — A linear system must satisfy both additivity and homogeneity. The system $y(t) = 5 \cdot x(t) + 3$ fails homogeneity because scaling x by zero does not produce zero output ($y = 3$ when $x = 0$). Constant offsets violate linearity, making the system affine rather than linear.
46. A — The Final Value Theorem gives the steady-state response to a unit step as $H(0) = (0 + 1)/(0 + 0 + 5) = 1/5 = 0.2$. The theorem applies because all poles of $H(s)$ are in the left-half plane. This shortcut avoids computing the full time-domain response.
47. D — In an LTI system, the impulse response $h[n]$ is the complete characterization: any output can be computed by convolving $h[n]$ with the input. The impulse response encodes every aspect of the system's behavior. This is why $h[n]$ is sometimes called the system's signature.
48. C — The Laplace pair $L\{\cos(\omega t) \cdot u(t)\} = s/(s^2 + \omega^2)$ is the standard transform for sinusoidal signals starting at $t = 0$. It is essential for analyzing AC steady-state responses and the transient response of resonant circuits. The companion pair for sine is $\omega/(s^2 + \omega^2)$.
49. B — For an integrator $H(s) = 1/s$, substitute $s = j\omega$: $H(j\omega) = 1/(j\omega) = -j/\omega$. Magnitude is $|H(j\omega)| = 1/\omega$ and phase is -90° . The integrator's -20 dB/decade slope and constant -90° phase are signature features on Bode plots.
50. D — The Nyquist-Shannon sampling theorem requires that the sampling rate $f_s \geq 2 \cdot f_{\max}$ for distortionless reconstruction. Sampling below this rate causes components above $f_s/2$ to fold back into the baseband, corrupting the signal. The theorem is fundamental to all digital signal processing.
51. A — The Nyquist frequency is half the sampling rate: $f_{\max} = f_s/2 = 8/2 = 4$ kHz. Signals with components above 4 kHz alias when sampled at 8 kHz. Anti-aliasing filters must attenuate above this frequency before the sampler.
52. C — The Fast Fourier Transform reduces DFT complexity from $O(N^2)$ to $O(N \cdot \log N)$ by recursively decomposing the transform into smaller subtransforms. For $N = 1024$, this is a roughly 100-fold speedup. The FFT made real-time spectral analysis practical and is one of the most impactful algorithms in engineering.
53. B — The difference equation $y[n] = x[n] - x[n - 1]$ approximates a discrete-time derivative, attenuating low frequencies (where consecutive samples are nearly equal) and passing high frequencies. The transfer function $H(z) = 1 - z^{-1}$ has a zero at $z = 1$ (DC), confirming highpass behavior. This is the simplest FIR highpass filter.
54. D — The highest frequency component is 300 Hz. Nyquist requires $f_s \geq 2 \cdot f_{\max} = 2 \cdot 300 = 600$ Hz to avoid aliasing. Any lower sampling rate would corrupt the 300 Hz component, and practical systems sample above the minimum to relax anti-aliasing filter requirements.
55. D — The autocorrelation function at zero lag is $R_{xx}(0) = E[x^2(t)]$, which equals the mean-square value of the signal — its total average power. For a zero-mean signal, $R_{xx}(0)$ also equals the variance. $R_{xx}(0)$ is the maximum of the autocorrelation function for any stationary signal.
56. C — A forward-biased silicon p-n junction has a built-in voltage barrier of about 0.6–0.7 V at room temperature, set by the band gap and doping levels. Below this voltage, the diode conducts negligibly; above it, current rises exponentially. Germanium drops about 0.3 V and LEDs typically 1.6–3.5 V depending on wavelength.

57. B — The small-signal voltage gain of a common-source NMOS amplifier with drain resistor R_D is $A_v = -g_m R_D$. The negative sign indicates 180° phase inversion between gate input and drain output. This is the MOSFET analog of the BJT common-emitter gain expression.
58. A — The BJT active region requires the base-emitter junction forward-biased (to inject minority carriers) and the base-collector junction reverse-biased (to collect them efficiently). When both junctions are forward-biased, the transistor saturates; when both are reverse-biased, it is in cutoff. The active region is where useful amplification occurs.
59. C — Non-inverting op-amp closed-loop gain: $A = 1 + R_f/R_1 = 1 + 90/10 = 10$. The "+1" reflects the direct path from the non-inverting input. This contrasts with the inverting topology, where the gain is simply $-R_f/R_1$.
60. A — In the JFET saturation region, the drain current follows the square-law expression $I_D = I_{DSS} \cdot (1 - V_{GS}/V_{PS})^2$, depending only on V_{GS} once V_{DS} exceeds the saturation voltage. Channel-length modulation introduces a small V_{DS} dependence usually neglected in first-order analysis. This is the analog signal-processing region for the JFET.
61. B — A Zener voltage reference produces its most stable output voltage when biased at a current within its specified operating range, where the V-I curve is steep and the dynamic resistance is small. Operating too close to the knee yields a softer breakdown and worse regulation. Constant Zener current is the design target for precision references.
62. C — The common-mode rejection ratio is the ratio of differential-mode gain A_d to common-mode gain A_{cm} : $CMRR = A_d/A_{cm}$, usually expressed in decibels. High CMRR means the amplifier suppresses signals common to both inputs (such as power-line noise) while amplifying the difference. CMRR is a critical specification for instrumentation amplifiers.
63. D — In static CMOS operation, both nMOS and pMOS transistors have one device fully off, blocking DC current paths. Power dissipation in this state is dominated by subthreshold leakage and gate leakage through both transistors. As technology nodes shrink, leakage has grown into a significant fraction of total power consumption.
64. A — For a Y-connected balanced load, $V_{phase} = V_{LL}/\sqrt{3} = 400/\sqrt{3} \approx 231$ V. The line-to-line voltage relates to phase voltage by $\sqrt{3}$ in Y connection (voltages relate by $\sqrt{3}$ in Y, currents in Δ). This relationship is essential for three-phase load analysis.
65. B — The power triangle relates real power P, reactive power Q, and apparent power S by $S^2 = P^2 + Q^2$. P is the active in-phase component, Q is the quadrature component, and S is the vector sum. The triangle is the basis for power-factor correction analysis.
66. D — Synchronous speed is fixed by line frequency and pole count: $n_s = 120 \cdot 60/4 = 1,800$ rpm. Rotor speed under slip s: $n = n_s \cdot (1 - s) = 1,800 \cdot (1 - 0.03) = 1,746$ rpm. Slip is necessary in induction machines to develop torque.
67. A — Transformer efficiency is maximized when load-dependent copper (I^2R) losses equal load-independent core (iron) losses. Below this point, fixed core losses dominate; above it, copper losses grow as the square of current. This balance is the design target for transformer loading optimization.
68. C — In a synchronous machine, mechanical frequency equals electrical frequency divided by the number of pole pairs: $f_{mech} = f_{elec}/(P/2) = 60/2 = 30$ Hz. This corresponds to 1,800 rpm rotor speed ($30 \text{ rev/s} \times 60 \text{ s/min}$). Pole count is the primary design parameter for matching speed to line frequency.
69. B — Power-factor correction in industrial systems is most commonly accomplished by installing shunt capacitor banks that supply reactive power locally to inductive loads. This reduces the

apparent power drawn from the utility and avoids low-PF penalty charges. Synchronous condensers and static VAR compensators provide more advanced correction options.

70. D — Per-unit values are defined as actual / base, so $V_{pu} = 13.8/13.8 = 1.0$ at rated voltage. The base voltage normalizes the system to dimensionless quantities for easier analysis across multiple voltage levels. Per-unit analysis is standard practice in power-system fault and load-flow studies.
71. C — The armature winding of a DC machine carries the load (working) current that interacts with the field-produced flux to generate either torque (motor mode) or back-EMF (generator mode). The field winding carries only the much smaller excitation current. This separation of functions is fundamental to DC machine design.
72. A — A line-commutated thyristor rectifier controls the average DC output voltage by varying the firing (delay) angle α relative to the natural zero-crossing of the source. Larger α delays conduction and reduces the integrated output. Phase control has dominated industrial DC drives and HVDC link applications for decades.
73. B — Gauss's Law states that the net electric flux through any closed surface equals the enclosed charge divided by the permittivity: $\oint \mathbf{E} \cdot d\mathbf{A} = Q_{enc}/\epsilon_0$. The law follows from the inverse-square nature of the Coulomb force. Gauss's Law is one of Maxwell's four equations and is essential for symmetric field problems.
74. D — Coulomb's law gives the field magnitude $E = k \cdot q/r^2 = (9 \times 10^9) \cdot (10^{-6})/1^2 = 9 \times 10^3$ V/m at 1 m from a 1 μC point charge. The field strength scales inversely with the square of distance. This value provides a useful reference for problem checking.
75. C — The characteristic impedance of a coaxial cable is $Z_0 = (\eta/2\pi) \cdot \ln(b/a)$, where b/a is the outer-to-inner conductor radius ratio and η depends on the dielectric permittivity. Both geometric and material properties determine Z_0 . Common standard values include 50 Ω for RF and 75 Ω for video/CATV.
76. A — The intrinsic impedance of free space is $\eta_0 = \sqrt{(\mu_0/\epsilon_0)} \approx 377 \Omega$. This impedance gives the ratio of E to H in a plane wave propagating through vacuum. It is the reference impedance for antenna and wave-propagation calculations.
77. D — For an underdamped second-order system, the 2% settling time is $t_s \approx 4/(\zeta\omega_n)$. This approximation reflects the time for the exponential envelope $e^{-(\zeta\omega_n \cdot t)}$ to decay to about 0.02. The 1% settling criterion uses $4.6/(\zeta\omega_n)$ instead.
78. B — The proportional gain K_p scales the error directly, which speeds up the system response and reduces (but does not eliminate) steady-state error. Increasing K_p too much reduces stability margin and can cause oscillation. The integral term, not K_p , is what completely eliminates steady-state error.
79. C — Construct the Routh array for $s^3 + 5s^2 + 8s + 6$: row $s^3 = [1, 8]$, row $s^2 = [5, 6]$, row $s^1 = [(5 \cdot 8 - 1 \cdot 6)/5, 0] = [6.8, 0]$, row $s^0 = [6]$. All first-column entries are positive, confirming closed-loop stability. The Routh-Hurwitz test detects right-half-plane roots without computing them explicitly.
80. A — Unity-feedback closed-loop transfer function: $T(s) = G/(1 + G) = [10/(s + 2)] / [1 + 10/(s + 2)] = 10/(s + 12)$. The closed-loop pole moves from -2 to -12 , demonstrating how feedback increases system speed. This is a textbook example of pole movement under feedback.
81. D — In root-locus construction, branches begin at the open-loop poles ($K = 0$) and end at the open-loop zeros ($K \rightarrow \infty$). When there are fewer finite zeros than poles, the excess branches terminate at infinity along asymptotes. Knowing the termination points is essential for sketching the locus.
82. B — The phase margin is the additional phase lag (beyond what already exists at the gain-crossover frequency) needed to reach -180° . The gain-crossover frequency is where $|G(j\omega)| = 0$ dB (unity

magnitude). Phase margin and gain margin together characterize relative stability in the frequency domain.

83. C — A PI controller integrates the error signal, accumulating any persistent error until the integral term drives the output to eliminate it. For step inputs, this guarantees zero steady-state error in a stable closed loop. Integral action is what makes PI control widely used in process control applications.
84. A — Single-sideband modulation transmits only one of the two sidebands produced by amplitude modulation, halving the required bandwidth compared to DSB. Power efficiency also improves because no power is wasted on the redundant sideband or carrier in SSB-SC. SSB is preferred for voice transmission in HF radio.
85. D — A QPSK constellation has $4 = 2^2$ states, so each symbol carries $\log_2(4) = 2$ bits. Higher-order PSK and QAM systems achieve more bits per symbol at the cost of reduced noise margin between constellation points. The bits-per-symbol count determines the spectral efficiency.
86. B — Shannon's channel capacity formula for an AWGN channel is $C = B \cdot \log_2(1 + \text{SNR})$, expressed in bits per second. This sets the theoretical upper bound on error-free data transmission for given bandwidth and signal-to-noise ratio. Real systems approach but never exceed this bound.
87. A — A matched filter is the linear filter whose impulse response is the time-reversed (and conjugated) signal template. It maximizes the signal-to-noise ratio at the sampling instant in additive white Gaussian noise. This optimization underlies the receiver structure of essentially all modern digital communication systems.
88. C — Direct-sequence spread spectrum multiplies the data by a high-rate pseudorandom code, spreading the signal energy over a wider bandwidth. Narrowband interference is then suppressed by the processing gain during de-spreading at the receiver. Spread spectrum also provides resistance to multipath fading and supports CDMA multiple access.
89. C — The OSI Transport layer (Layer 4) provides end-to-end reliable delivery between endpoints, using protocols such as TCP that handle segmentation, sequencing, acknowledgment, and retransmission. Lower layers handle hop-by-hop concerns rather than end-to-end reliability. Layer 4 is where applications obtain their connection abstraction.
90. D — The TCP three-way handshake establishes a connection through SYN (client to server, with initial sequence number), SYN-ACK (server to client, acknowledging client's SYN and providing its own), then ACK (client to server, acknowledging the server). All three messages are required before data transfer begins. The handshake also negotiates initial sequence numbers and options.
91. B — The standard maximum cable length for Cat6 Ethernet at 1 Gbps is 100 meters, the same as Cat5e at 1 Gbps. Beyond 100 m, signal attenuation and timing margin become inadequate for reliable transmission. This length applies to a single cable run including patch cords on each end.
92. A — BGP (Border Gateway Protocol) is the inter-domain routing protocol used to exchange reachability information between autonomous systems on the Internet. BGP makes the global Internet possible by coordinating routing decisions across thousands of administratively independent networks. Internal routing within an AS typically uses OSPF or IS-IS instead.
93. D — Convert binary 1101 0110 by summing weighted bits: $1 \cdot 128 + 1 \cdot 64 + 0 \cdot 32 + 1 \cdot 16 + 0 \cdot 8 + 1 \cdot 4 + 1 \cdot 2 + 0 \cdot 1 = 128 + 64 + 16 + 4 + 2 = 214$. Each binary digit represents a power of 2, doubling from right to left. This is direct positional notation evaluation.
94. C — The distributive law of Boolean algebra states that $A \cdot (B + C) = A \cdot B + A \cdot C$, mirroring the distribution of multiplication over addition in ordinary arithmetic. The dual form $A + (B \cdot C) = (A + B) \cdot (A + C)$ also holds in Boolean algebra (unlike ordinary arithmetic). These identities are central to logic simplification.

95. C — A 4-to-1 multiplexer routes one of $4 = 2^2$ inputs to the output, requiring $\log_2(4) = 2$ select lines. Each combination of select bits uniquely addresses one input. More generally, an n-to-1 MUX needs $\lceil \log_2 n \rceil$ select lines.
96. D — An SR latch with $S = 1$ and $R = 0$ enters the set state, driving $Q = 1$. The other combinations are reset ($S = 0, R = 1 \rightarrow Q = 0$), hold ($S = R = 0$), and forbidden ($S = R = 1$). Understanding all four input combinations is essential for sequential logic design.
97. B — A D-type flip-flop is edge-triggered, capturing the D input on the active clock edge (typically rising). Between clock edges, Q is held regardless of D changes. Edge triggering avoids the transparency problems of level-sensitive latches and is the foundation of synchronous digital design.
98. A — With 8-bit two's complement, the representable signed range is -2^7 to $2^7 - 1$, or -128 to $+127$. The asymmetric range arises because zero takes one of the positive codes. Two's complement is universal in modern computing because addition and subtraction work identically to unsigned arithmetic.
99. B — A combinational logic circuit produces output that depends only on the current input values, with no memory or feedback. Sequential circuits, by contrast, depend on both current inputs and stored state. The distinction is fundamental: combinational logic implements Boolean functions, sequential logic implements state machines.
100. D — An n-input AND gate produces a HIGH output only when every input is HIGH; any LOW input forces the output LOW. This corresponds to multiplying input values in Boolean algebra ($1 \cdot 0 = 0$). AND-OR networks form the canonical sum-of-products realization of Boolean functions.
101. A — A 3-bit binary counter has $2^3 = 8$ possible state values (000 through 111), cycling through all eight before rolling over to 000. The count sequence is 0, 1, 2, ..., 7, 0, 1, ... in continuous operation. Counter modulus determines its application as a divider, sequencer, or address generator.
102. C — A structural hazard arises when two stages of the pipeline simultaneously demand the same physical hardware resource, such as a single memory port or shared functional unit. The conflict forces a pipeline stall. Modern designs typically eliminate structural hazards by duplicating resources or pipelining the resource itself.
103. B — Cache line size is 64 bytes, requiring $\log_2(64) = 6$ bits to address any byte within a line. These 6 offset bits select the byte position once a line is located. The remaining address bits split between index (which line) and tag (which memory block maps there).
104. A — Virtual memory provides each process with a logical address space larger than physical RAM by paging blocks of memory between RAM and disk as needed. This abstraction simplifies programming and enables concurrent execution of large programs on modest hardware. Page tables managed by the OS translate virtual to physical addresses on every memory access.
105. D — Amdahl's Law states that maximum speedup $= 1 / [(1 - p) + p/N]$, where p is the parallelizable fraction. As $N \rightarrow \infty$, the speedup approaches $1 / (1 - p)$, set by the serial portion of the program. This fundamental limit motivates the focus on reducing the serial fraction in parallel workloads.
106. C — RISC architectures are characterized by fixed-length instructions, simple addressing modes, a load/store data flow, and a large register file. Uniform instructions simplify pipeline design and allow higher clock frequencies. The RISC philosophy dominates modern processors (ARM, RISC-V, and the internal decode of modern x86).

107. A — The Waterfall model is a strictly linear development process: requirements gathering, design, implementation, testing, deployment, and maintenance, each phase completed before the next begins. Backward iteration is minimized or forbidden. The Waterfall approach is contrasted with iterative and Agile methodologies that revisit phases continuously.
108. B — Encapsulation bundles a class's data (state) and methods (behavior) together, with access modifiers (public, private, protected) controlling visibility from outside the class. This protects internal state from arbitrary modification and exposes only the intended interface. Encapsulation is one of the four pillars of object-oriented programming.
109. C — Unit testing verifies the behavior of individual functions, methods, or small modules in isolation, typically with mocked dependencies. It is the most granular test level and forms the base of the testing pyramid. Integration and system testing build on top of unit-level confidence to verify component interactions.
110. A — Code review is a peer examination of source code aimed at finding defects, improving design, ensuring style consistency, and sharing knowledge across the team before code is merged. It is one of the most cost-effective defect-detection practices in software engineering. Code reviews complement, but do not replace, formal testing.