PRACTICE EXAM 18: FE ELECTRICAL AND COMPUTER SIMULATION (110 QUESTIONS)

Time allotted: 5 hours 20 minutes

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

1. Find the eigenvalues of the matrix A = [[5, −2], [−2, 5]].

A. 3 and 7

B. 5 and −5

C. 0 and 10

D. −3 and −7

2. Evaluate the definite integral $\int_0^{\pi/2} \sin^3(x)\, dx$.

A. 1/3

B. 2/3

C. π/4

D. 1

3. Find the derivative of f(x) = x^x evaluated at x = e.

A. e^e

B. e^(e+1)

C. $e^e + 1$

D. $2 \cdot e^e$

4. Solve the linear system $2x + y = 7$ and $x - y = 2$ simultaneously.

A. $x = 1$, $y = -1$

B. $x = 4$, $y = -1$

C. $x = 3$, $y = 1$

D. $x = 2$, $y = 0$

5. What is the fundamental period of the function $f(t) = 3 \cdot \cos(4t) + 2 \cdot \sin(6t)$?

A. $\pi/12$

B. π

C. 2π

D. $\pi/2$

6. Find the unit vector in the direction of $v = (3, 4, 0)$.

A. (3/5, 4/5, 0)

B. (3, 4, 0)

C. (1/3, 1/4, 0)

D. (3/7, 4/7, 0)

7. Classify the critical point at (0, 0) for the function $f(x, y) = x^2 - 2xy + 3y^2$.

A. Local maximum (negative definite Hessian)

B. Saddle point (indefinite Hessian)

C. Local minimum (positive definite Hessian)

D. Inflection point (singular Hessian)

8. Compute the convolution $(f * g)(t)$ where $f(t) = u(t)$ and $g(t) = e^{-t} \cdot u(t)$.

A. $t \cdot e^{-t} \cdot u(t)$

B. $e^{-t} \cdot u(t)$

C. $u(t)$

D. $(1 - e^{-t}) \cdot u(t)$

9. For the complex equation $z^2 = -16$, find the principal root (the solution with positive imaginary part).

A. 4

B. 4j

C. −4

D. −4j

10. Apply Stokes' theorem to compute $\oint F \cdot dr$ around a closed curve C bounding a disk of radius 2 in the xy-plane, where $F = \langle y, -x, 0 \rangle$.

A. -8π

B. 8π

C. 0

D. 16π

11. Find the area enclosed by the polar curve $r = 2 \cdot \cos \theta$.

A. 4π

B. 2π

C. π

D. $\pi/2$

12. For the differential equation $y'' + 6y' + 13y = 0$, the general solution has the form:

A. $y = (C_1 + C_2 \cdot x) \cdot e^{(-3x)}$

B. $y = C_1 \cdot e^{(-3x)} + C_2 \cdot e^{(3x)}$

C. $y = C_1 \cdot \cos(2x) + C_2 \cdot \sin(2x)$

D. $y = e^{(-3x)} \cdot [C_1 \cdot \cos(2x) + C_2 \cdot \sin(2x)]$

13. The Maclaurin series of $f(x) = e^x$ truncated through the x^3 term is:

A. $1 + x + x^2/2 + x^3/3$

B. $1 + x + x^2/2 + x^3/6$

C. $1 + x + x^2 + x^3$

D. $x + x^2/2 + x^3/6$

14. A fair coin is flipped 5 times. The probability of getting exactly 3 heads is:

A. 5/16

B. 1/2

C. 1/8

D. 3/5

15. Two random variables X and Y have $\sigma^2_X = 4$ and $\sigma^2_Y = 9$, with covariance $Cov(X, Y) = 3$. The variance of X + Y is:

A. 13

B. 25

C. 19

D. 6

16. For a normal distribution with mean $\mu = 50$ and standard deviation $\sigma = 10$, the 95th percentile (using $z = 1.645$) is approximately:

A. 50

B. 60

C. 66.45

D. 95

17. A bag contains 3 red balls and 7 blue balls. Two balls are drawn without replacement. The probability that both are red is:

A. 9/100

B. 3/10

C. 1/10

D. 1/15

18. A licensed PE is asked to act as an expert witness in a lawsuit where their employer is the defendant. The PE may serve in this role:

A. Without restriction since expert testimony is protected speech

B. Only with full disclosure of the employment relationship and provided objectivity is maintained

C. Only after resigning from the employer

D. Never, due to inherent conflict of interest

19. An engineer is offered a substantial bonus by their employer to expedite a project, but doing so would require skipping required safety inspections. The engineer should:

A. Refuse the bonus and insist on completing all required safety inspections

B. Accept the bonus and reduce the inspection scope to match

C. Accept the bonus and continue safety inspections in private

D. Delegate the work to a subordinate to maintain plausible deniability

20. An engineer reviewing a colleague's design discovers a significant calculation error that would cause structural failure if built. The engineer should:

A. Quietly correct the error without informing anyone else

B. Inform only the project manager and let them handle disclosure

C. Wait for the colleague to discover and correct the error

D. Notify the colleague, document the error, and verify the correction before construction proceeds

21. A PE provides engineering services to multiple clients simultaneously, with one client unaware that the engineer also serves a competing firm. Per the NSPE Code, the engineer must:

A. Continue providing services until directly asked about other clients

B. Disclose the multi-client relationship to all affected parties in writing

C. Choose one client and terminate the other relationships

D. Continue all relationships without disclosure since the work products differ

22. A capital project requires $100,000 today and returns $40,000 per year for 3 years. At MARR = 10% with (P/A, 10%, 3) = 2.4869, the Net Present Worth is:

A. −$524

B. +$524

C. $0 (project at break-even exactly)

D. +$20,000

23. Two mutually exclusive alternatives have the same study period: Alternative A has PW = \$50,000; Alternative B has PW = \$48,000. The preferred alternative is:

A. The two are equivalent within rounding

B. Alternative B due to its lower present worth value

C. Alternative A due to its higher present worth value

D. Cannot be determined without additional information

24. For a project with cash flows −\$10,000 (year 0) and +\$2,500/year for 5 years, the simple payback period is:

A. 5 years

B. 2 years

C. 1 year

D. 4 years

25. A 10-year loan of \$500,000 at 5% APR compounded annually has an annual payment of, using (A/P, 5%, 10) = 0.1295:

A. \$50,000

B. \$25,950

C. \$129,500

D. \$64,750

26. Using straight-line depreciation from initial value \$80,000 with salvage value \$20,000 over 5 years, the book value at the end of year 3 is:

A. \$44,000

B. \$48,000

C. \$56,000

D. $60,000

27. In an n-type semiconductor at room temperature, the Fermi level lies:

A. At the middle of the band gap

B. Above the conduction band edge

C. Closer to the conduction band edge than to the valence band edge

D. Below the valence band edge

28. The temperature coefficient of resistance (TCR) for copper at 20°C is approximately:

A. 0 (resistance is independent of temperature)

B. +0.00393 per °C

C. −0.00393 per °C

D. −0.0001 per °C (semiconductor-like behavior)

29. In a semiconductor with electron mobility μ_n = 1,350 $cm^2/(V\cdot s)$ and electron density n = 10^{16} cm^{-3}, the conductivity contribution from electrons in S/cm is:

A. 2.16

B. 21.6

C. 0.216

D. 216

30. A ferroelectric material exhibits:

A. Permanent net magnetic moment in the bulk

B. Spontaneous electric polarization that can be reversed by an external electric field

C. Spontaneous mechanical strain without any applied field

D. Zero dielectric constant under all conditions

31. A 12 V battery has an internal resistance of 0.5 Ω. When the battery supplies a 6 A current to an external load, the terminal voltage is:

A. 12.0 V

B. 6.0 V

C. 9.0 V

D. 11.0 V

32. A 200 μF capacitor initially charged to 50 V discharges through a 1 kΩ resistor. The time required for the capacitor voltage to drop to 10 V is approximately:

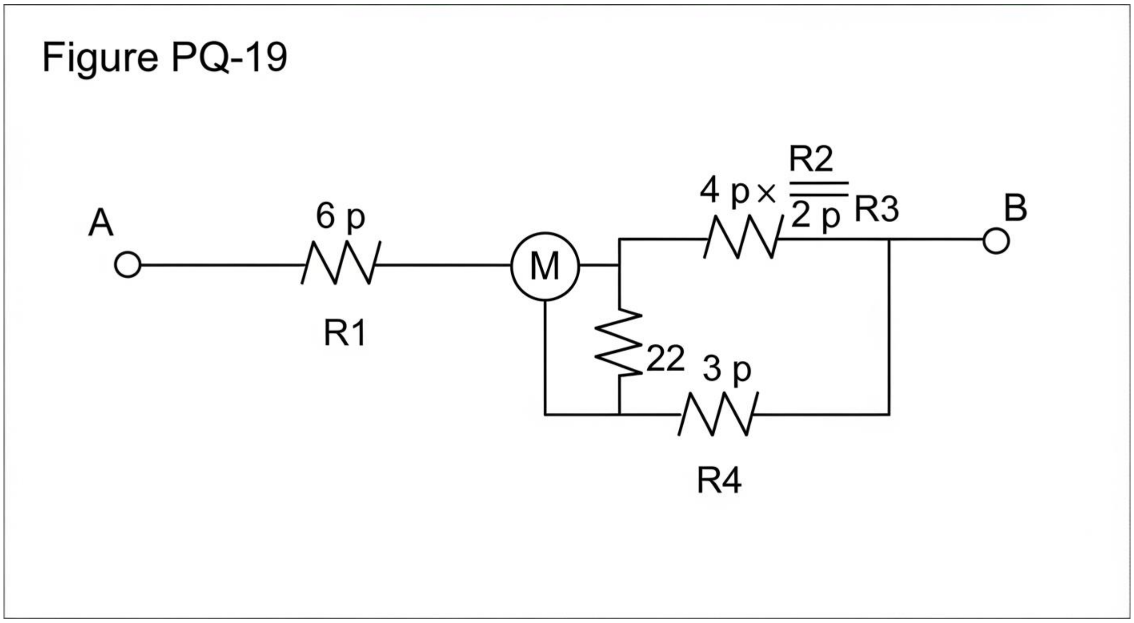
A. 0.322 s

B. 0.500 s

C. 1.000 s

D. 0.100 s

33. For the series-parallel resistor network shown in the figure, the equivalent resistance between terminals A and B is:



A. 11 Ω

B. 8 Ω

C. 12 Ω

D. 9 Ω

34. A 240 V, 60 Hz AC source drives a series circuit with R = 30 Ω and L = 100 mH. The rms current magnitude is:

A. 8.0 A

B. 5.0 A

C. 4.6 A

D. 3.0 A

35. For a three-phase Y-connected source with phase voltage 277 V (rms), the line-to-line voltage is approximately:

A. 277 V

B. 554 V

C. 392 V

D. 480 V

36. A series LC circuit with L = 100 mH and C = 10 μF exhibits resonance at approximately:

A. 50 Hz

B. 60 Hz

C. 159 Hz

D. 1,592 Hz

37. The phasor representation of $v(t) = 100 \cdot \cos(\omega t + 30°)$ is:

A. $100\angle 30°$

B. $100\angle -30°$

C. $50\angle 30°$

D. $100\angle 60°$

38. An op-amp inverting amplifier has R_f = 100 kΩ in feedback and R_in = 5 kΩ at the inverting input. The closed-loop voltage gain is:

A. −10

B. −100

C. +20

D. −20

39. A series RLC circuit at resonance has R = 50 Ω, ω_0 = 1,000 rad/s, source voltage V_s = 10 V (rms), and Q = 10. The voltage magnitude across the inductor at resonance is:

A. 10 V

B. 50 V

C. 100 V

D. 1 V

40. Two impedances $Z_1 = 10 + j10\ \Omega$ and $Z_2 = 20 - j5\ \Omega$ are connected in series. The magnitude of the total impedance is:

A. 30 Ω

B. 35 Ω

C. 25 Ω

D. 30.4 Ω

41. In a 2-port network described by ABCD parameters, the parameter A represents:

A. The ratio of output current to input current

B. The ratio V_1/V_2 when the output is open-circuited ($I_2 = 0$)

C. The input impedance under all conditions

D. The power transfer ratio across the network

42. An ideal 10 V DC voltage source is connected in parallel with an ideal 2 A DC current source. The voltage across the combination is:

A. 0 V (the sources cancel)

B. 10 V if the magnitudes add; otherwise depends on polarity

C. 12 V (sum of the two sources)

D. 10 V (set entirely by the voltage source)

43. A black-box network has terminals A and B. Measurements give $V_{AB} = 12$ V with the terminals open and $I_{short} = 3$ A flowing from A to B with terminals shorted. The Norton equivalent at A-B is:

A. $I_N = 12$ A, $R_N = 3\ \Omega$

B. $I_N = 12$ A, $R_N = 4\ \Omega$

C. $I_N = 3$ A, $R_N = 4\ \Omega$

D. $I_N = 3$ A, $R_N = 12\ \Omega$

44. For an LTI system with transfer function $H(s) = K/(s + a)$, the steady-state response amplitude to a step input of magnitude V is:

A. $V \cdot K/a$

B. $V \cdot K$

C. V/a

D. K

45. A discrete-time LTI system has a pair of poles at $z = 0.9 \cdot e^{(\pm j\pi/4)}$, both inside the unit circle. The impulse response is:

A. Unstable and growing without bound

B. Marginally stable (constant amplitude oscillation)

C. Causal but unbounded for large n

D. Stable, with an oscillating but decaying envelope

46. The Laplace transform of t^2 (for $t \geq 0$) is:

A. $1/s^2$

B. $2/s^3$

C. $1/s^3$

D. s^2

47. For a continuous-time system with impulse response $h(t) = e^{(-2t)} \cdot u(t)$, the DC gain is:

A. 1/2

B. 2

C. 1

D. 0

48. A causal LTI system has transfer function $H(s) = 5(s + 3) / [(s + 1)(s + 2)(s + 4)]$. The order of the system is:

A. 1

B. 2

C. 3

D. 4

49. In a state-space representation $\dot{x} = Ax + Bu$, $y = Cx + Du$, the matrix A is called:

A. The input matrix

B. The output matrix

C. The direct transmission matrix

D. The state (system) matrix

50. A continuous-time signal $x(t) = \cos(2\pi \cdot 1{,}000 \cdot t)$ is sampled at 1,500 Hz. The reconstructed (aliased) baseband frequency is:

A. 1,000 Hz

B. 500 Hz

C. 750 Hz

D. 1,500 Hz

51. A 1,024-point FFT of a signal sampled at 8 kHz provides frequency resolution of:

A. 7.8125 Hz

B. 8,000 Hz

C. 1,024 Hz

D. 4,000 Hz

52. For the discrete-time signal $x[n] = \delta[n] + 2\cdot\delta[n - 1] - \delta[n - 2]$, the z-transform $X(z)$ is:

A. $1 + 2z + z^2$

B. $z + 2 - z^{-1}$

C. $1 + 2z^{-1} - z^{-2}$

D. $1 - 2z^{-1} + z^{-2}$

53. The Hamming window applied in FFT analysis is used primarily to:

A. Eliminate quantization noise in the converted signal

B. Reduce computational complexity of the FFT itself

C. Increase the signal-to-noise ratio of the data

D. Reduce spectral leakage at the edges of the analysis window

54. Decimating a discrete-time signal by a factor M produces:

A. A higher effective sampling rate

B. A lower sampling rate by keeping every M-th sample only

C. An upsampled version of the original signal

D. The same effect as zero-padding the data

55. An FIR filter with $N = 5$ taps has an impulse response length of:

A. 4 samples (one less than N)

B. ∞ (infinite duration)

C. 5 samples (equal to N)

D. N + 1 samples

56. A BJT with $\beta = 100$ and base current $I_B = 50\ \mu A$ operates in the active region. The collector current is:

A. 5 mA

B. 50 mA

C. 0.5 mA

D. 100 mA

57. An NMOS transistor operates in saturation with $V_{GS} = 3$ V, $V_T = 1$ V, and $\mu_n \cdot C_{ox} \cdot (W/L) = 2\ mA/V^2$. The drain current is:

A. 4 mA

B. 2 mA

C. 8 mA

D. 1 mA

58. In a common-source MOSFET amplifier, an unbypassed source resistor R_S provides:

A. An increased small-signal voltage gain at signal frequencies

B. Reduced small-signal voltage gain with improved linearity (source degeneration)

C. Elimination of the bias network entirely

D. Doubling of the input impedance of the amplifier

59. In a differential pair amplifier, the input common-mode range is limited primarily by:

A. The output saturation voltage of the load

B. The Early voltage of the input transistors

C. The voltage headroom needed for the tail current source biasing the pair

D. The thermal noise of the source resistors

60. A Schottky diode differs from a conventional silicon p-n junction diode in that:

A. It has noticeably higher forward voltage drop

B. It always uses germanium instead of silicon

C. It exhibits higher reverse leakage current as its main feature

D. It uses a metal-semiconductor junction with lower forward drop and faster switching

61. In a CMOS op-amp configured for unity gain, the closed-loop bandwidth equals approximately:

A. Zero (the op-amp is non-functional)

B. The open-loop unity-gain frequency (gain-bandwidth product)

C. Infinity (the bandwidth is unlimited)

D. Twice the open-loop gain in dB

62. A Wien-bridge oscillator with R = 10 kΩ and C = 16 nF oscillates at approximately:

A. 100 kHz

B. 6.28 kHz

C. 995 Hz

D. 1.59 kHz

63. In a buck (step-down) switched-mode converter operating in continuous conduction mode, the relationship between output voltage V_out and input voltage V_in is:

A. $V_{out} = D \cdot V_{in}$ (where D is the switch duty cycle)

B. $V_{out} = V_{in} / D$

C. $V_{out} = (1 - D)/D \cdot V_{in}$

D. $V_{out} = V_{in}$ (no conversion ratio)

64. A 60 Hz, six-pole three-phase synchronous motor operates at synchronous speed. The mechanical rotational speed is:

A. 3,600 rpm

B. 1,800 rpm

C. 900 rpm

D. 1,200 rpm

65. To halve the I^2R conductor losses on a three-phase transmission line while delivering the same total power, the line voltage must be:

A. Doubled (factor of 2)

B. Multiplied by $\sqrt{2}$

C. Halved

D. Quadrupled

66. The slip of a 60 Hz, 4-pole three-phase induction motor running at 1,750 rpm is:

A. 2.78%

B. 5%

C. 1.5%

D. 10%

67. A balanced three-phase load drawing 30 kVA at 0.9 power factor lagging is supplied at 480 V (line-to-line). The line current is:

A. 18.0 A

B. 62.5 A

C. 36.1 A

D. 72.2 A

68. A 50 kVA, 2,400/240 V transformer has rated full-load efficiency of 97% at unity power factor. If the no-load core losses are 500 W, the full-load copper losses are approximately:

A. 0 W

B. 500 W

C. 1,000 W

D. 1,047 W

69. A capacitor bank of 140 kVAR is added to a load drawing 200 kW at 0.7 power factor lagging. The new power factor of the combination is closest to:

A. 0.85

B. 0.95

C. 0.70

D. 1.00

70. A three-phase induction motor draws 10 kVA at full load with 0.85 power factor lagging. The real power consumed by the motor is:

A. 10 kW

B. 11.8 kW

C. 8.5 kW

D. 7.0 kW

71. Increasing the field current of a DC shunt motor while keeping the terminal voltage constant will:

A. Have no measurable effect on the motor speed

B. Always increase the motor speed proportionally

C. Decrease the armature current draw significantly

D. Decrease the motor speed (because flux Φ increases)

72. A 100 kVA, 2,400/240 V transformer operates at full load on the secondary side. The full-load secondary current is approximately:

A. 416.7 A

B. 41.7 A

C. 100 A

D. 4.17 A

73. A long straight conductor carries 50 A of current. The magnetic field magnitude at 10 cm perpendicular distance from the wire is approximately:

A. 50 μT

B. 100 μT

C. 200 μT

D. 500 μT

74. An electromagnetic plane wave in free space has electric field amplitude E_0 = 100 V/m. The average power density (time-averaged Poynting vector magnitude) is:

A. 100 W/m^2

B. 50 W/m^2

C. 13.3 W/m^2

D. 1 W/m^2

75. A transmission line of characteristic impedance $Z_0 = 50\ \Omega$ is terminated by a load $Z_L = 100\ \Omega$. The reflection coefficient at the load is:

A. 1/3

B. 1 (full reflection)

C. 0.5

D. −1/3

76. The skin depth δ in a conductor changes with frequency f as:

A. $\delta \propto \sqrt{f}$ (increases with frequency)

B. $\delta \propto 1/\sqrt{f}$ (decreases as frequency rises)

C. $\delta \propto f$ (linear increase)

D. $\delta \propto 1/f$ (inverse-linear decrease)

77. For a unity-feedback control system with open-loop transfer function $G(s) = K / [s\cdot(s + 5)\cdot(s + 10)]$, the maximum value of K for closed-loop stability (per the Routh-Hurwitz criterion) is:

A. 150

B. 50

C. 500

D. 750

78. A continuous-time PI controller has transfer function $K_p + K_i/s$. The Bode magnitude slope at very low frequencies is:

A. 0 dB per decade (flat)

B. −10 dB per decade

C. +20 dB per decade

D. −20 dB per decade

79. A feedback control system has phase margin = 45° and gain margin = 6 dB. The system is:

A. Unstable due to insufficient margins

B. Marginally stable (on the boundary)

C. Stable with adequate margins (PM > 30°, GM > 0 dB)

D. Optimally tuned for fastest response

80. A state-space realization in which the system matrix A is diagonal has the property that:

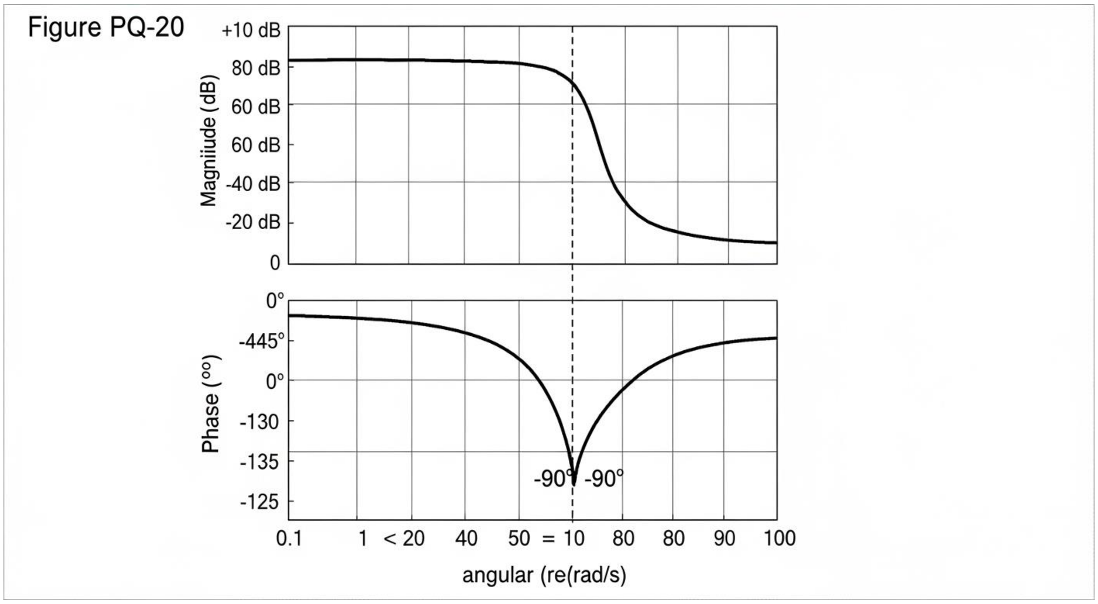
A. The natural modes (eigenmodes) are decoupled, with each state evolving independently

B. The system is always uncontrollable from any single input

C. The output matrix C must necessarily be zero

D. The input matrix B must also be diagonal in any realization

81. From the Bode magnitude and phase plots of the second-order system shown, the natural frequency ω_n is approximately:



A. ω_n ≈ 5 rad/s

B. ω_n ≈ 10 rad/s

C. ω_n ≈ 100 rad/s

D. ω_n ≈ 1 rad/s

82. In a root locus, two branches departing from the real axis meet at the imaginary axis at a particular gain value. At that gain, the closed-loop system is:

A. Stable with adequate stability margins

B. Underdamped with positive damping ratio

C. On the boundary of stability (purely imaginary poles, sustained oscillation)

D. Unstable with exponentially growing response

83. On a Bode magnitude plot of an open-loop transfer function, increasing the loop gain by a factor of K shifts the magnitude curve:

A. Upward by $20 \cdot \log_{10}(K)$ dB at all frequencies

B. Downward by $20 \cdot \log_{10}(K)$ dB at all frequencies

C. With no effect on the plotted magnitude

D. By causing only a phase shift, not a magnitude change

84. For an AM signal $s(t) = A_c \cdot [1 + m \cdot \cos(2\pi \cdot f_m \cdot t)] \cdot \cos(2\pi \cdot f_c \cdot t)$, the modulation index m is defined as:

A. The ratio of carrier frequency to message frequency

B. The total transmitted signal power

C. The ratio f_c divided by f_m

D. The ratio of peak message amplitude to carrier amplitude

85. In a 256-QAM digital communication system, each transmitted symbol carries:

A. 4 bits of information

B. 8 bits of information

C. 16 bits of information

D. 256 bits of information

86. A communication channel has bandwidth B = 10 kHz and SNR = 30 dB (linear ratio = 1,000). The Shannon channel capacity is approximately:

A. 30 kbps

B. 10 kbps

C. 100 kbps

D. 300 kbps

87. In a digital communication system, increasing the bit rate while keeping bandwidth and noise constant generally produces:

A. No effect on the bit error rate

B. A decrease in the bit error rate (improved performance)

C. Improved overall signal-to-noise ratio

D. An increase in the bit error rate (E_b/N_0 decreases per bit)

88. The noise figure (NF) of an amplifier represents:

A. The degradation of the SNR by the amplifier ($F = SNR_{in}/SNR_{out}$)

B. The total power dissipated in the amplifier device

C. The maximum operating frequency the device supports

D. The minimum input signal amplitude required for detection

89. In TCP, the sliding window mechanism is used to:

A. Increase the maximum segment size of each packet

B. Allow multiple segments to be transmitted before acknowledgment, improving throughput

C. Reduce the total number of TCP connections to a server

D. Enable broadcast transmissions to all hosts on a subnet

90. The preamble field of an Ethernet frame is used primarily for:

A. Source address identification of the sender

B. Error detection across the payload

C. VLAN tagging and traffic prioritization

D. Bit-level synchronization between the transmitter and receiver

91. An IPv6 address has a total length of:

A. 128 bits

B. 32 bits

C. 64 bits

D. 256 bits

92. A virtual LAN (VLAN) operates at which layer of the OSI model?

A. Layer 1 (Physical)

B. Layer 3 (Network)

C. Layer 4 (Transport)

D. Layer 2 (Data Link)

93. Convert the hexadecimal value 0x2A to its 8-bit binary representation.

A. 00101001

B. 00100100

C. 00101010

D. 00100010

94. The Boolean expression (A·B′) + (A·B) simplifies to:

A. A

B. B

C. A + B

D. A·B

95. De Morgan's theorem in Boolean algebra states:

A. (A·B)′ = A·B′

B. $(A \cdot B)' = A' + B$ (one variable left uncomplemented)

C. $(A \cdot B)' = A' + B'$

D. $A \cdot B = A + B$

96. A 3-to-8 line decoder with active-high inputs and active-high outputs receives input pattern 101. The output state is:

A. $Y_3 = 1$ with all other outputs at 0

B. $Y_5 = 1$ with all other outputs at 0

C. $Y_5 = 0$ with all other outputs at 1

D. $Y_7 = 1$ with all other outputs at 0

97. A 4-bit binary up counter starts at state 0000. After 17 clock pulses (with no intervening reset), the counter shows:

A. 0001

B. 0000

C. 1111

D. 1110

98. In modern CMOS technology, the static (quiescent) power dissipation is dominated by:

A. Switching transitions during clock edges

B. AC coupling effects from capacitive loads

C. Resistive losses in transistor channels

D. Subthreshold leakage and gate leakage currents

99. In a synchronous sequential machine, all flip-flop state changes occur:

A. On random, asynchronous clock edges

B. Only on assertion of the asynchronous reset input

C. On the active edge of a common system clock

D. On independent clocks for each individual flip-flop

100. In a CMOS digital inverter, when the input V_in = V_DD (HIGH), the output is:

A. Floating (high impedance)

B. V_out = 0 (LOW), with NMOS on and PMOS off

C. V_out = V_DD (HIGH)

D. V_out = V_DD/2 (midway)

101. A 256 K × 8 RAM module has how many address input lines?

A. 16

B. 8

C. 18

D. 20

102. In the MESI cache coherence protocol, the 'M' state of a cache line indicates that:

A. Multiple cached copies of the line currently exist

B. The line has been modified locally and is not consistent with main memory

C. The line is shared (clean) among multiple caches

D. A memory operation on the line is currently in progress

103. In a five-stage pipelined CPU (IF, ID, EX, MEM, WB), a data hazard between back-to-back instructions where the second uses the result of the first is most directly mitigated by:

A. Static branch prediction

B. Aggressive cache prefetching

C. Inserting pipeline reset cycles

D. Forwarding results from EX or MEM stage to the next instruction

104. In a virtual memory system with 4 KB pages and 32-bit virtual addresses, the page offset field is:

A. 12 bits

B. 4 bits

C. 16 bits

D. 32 bits

105. A pipeline hazard caused by a conditional branch instruction is best resolved by:

A. Flushing the data cache and reloading

B. Stalling the memory subsystem

C. Branch prediction (with a possible misprediction penalty)

D. Forwarding the operand value through the pipeline

106. A 64-bit microprocessor with a 1 GHz clock and a maximum throughput of one instruction per cycle achieves a peak theoretical execution rate of:

A. 64 GIPS

B. 1 GIPS (one billion instructions per second)

C. 32 MIPS

D. 64 MIPS

107. The Liskov Substitution Principle (LSP) in object-oriented design states that:

A. Derived class objects must be substitutable for base class objects without breaking correctness

B. Inheritance hierarchies should be no more than two levels deep

C. Each class must expose exactly one public method

D. All classes must implement at least one interface definition

108. The term "technical debt" in software engineering refers to:

A. The capital cost of acquiring development tools and licenses

B. The cost of training new developers on a codebase

C. The dollar value of intellectual property captured in code

D. The implied future cost of choosing a quicker solution today over a better one that would take longer

109. The Singleton design pattern in object-oriented software ensures that:

A. Multiple instances of a class are created automatically as needed

B. Each method of the class is invoked at most one time

C. A class has at most one instance and provides global access to it

D. All objects communicate exclusively through a central message queue

110. In Git version control, the `rebase` operation:

A. Reapplies commits from one branch onto another for a linear history

B. Permanently deletes selected commits from the history

C. Merges branches while preserving both histories with merge commits

D. Pulls the latest changes from a remote repository

PRACTICE EXAM 18 – ANSWER KEY AND FULL ANSWER EXPLANATIONS

1. A — The characteristic equation $(5 - \lambda)^2 - 4 = 0$ gives $5 - \lambda = \pm 2$, yielding eigenvalues $\lambda = 3$ and $\lambda = 7$. The symmetric matrix structure produces real eigenvalues whose sum equals the trace (10). Symmetric matrices always have real eigenvalues, which is a critical property in physical systems.
2. B — The substitution $\sin^3 x = \sin x \cdot (1 - \cos^2 x)$ makes the integral elementary: $-\cos x + \cos^3 x/3$. Evaluating from 0 to $\pi/2$: $(0 + 0) - (-1 + 1/3) = 2/3$. Odd-power trigonometric integrals are typically handled by reserving one factor and converting the rest via the Pythagorean identity.
3. D — Rewrite $x^x = e^{(x \cdot \ln x)}$, so by the chain rule $f'(x) = x^x \cdot (\ln x + 1)$. At $x = e$: $f'(e) = e^e \cdot (1 + 1) = 2 \cdot e^e$. Logarithmic differentiation is the standard technique for variable-base, variable-exponent functions.
4. C — Adding the two equations eliminates y: $3x = 9$, so $x = 3$. Substituting back gives $y = 1$. Verification: $2(3) + 1 = 7$ and $3 - 1 = 2$ both hold, confirming the solution.
5. B — Each constituent sinusoid has period $T_1 = 2\pi/4 = \pi/2$ and $T_2 = 2\pi/6 = \pi/3$. The fundamental period of the sum is the least common multiple π, since $\pi/(\pi/2) = 2$ and $\pi/(\pi/3) = 3$ are both integers. Multi-frequency periodic signals require LCM-based reasoning to identify the true repetition interval.
6. A — Magnitude: $|v| = \sqrt{(9 + 16 + 0)} = 5$. Dividing each component by the magnitude gives the unit vector (3/5, 4/5, 0). Unit vectors carry direction information independent of magnitude and form the basis of directional cosines.
7. C — At (0, 0) both partial derivatives vanish. The Hessian H = [[2, −2], [−2, 6]] has determinant $12 - 4 = 8 > 0$ and $f_{xx} = 2 > 0$, so H is positive definite. By the second-derivative test, the critical point is a local minimum.
8. D — Compute the convolution: $\int_0^t 1 \cdot e^{(-(t-\tau))}\, d\tau = e^{(-t)} \cdot \int_0^t e^{\tau}\, d\tau = e^{(-t)} \cdot (e^t - 1) = 1 - e^{(-t)}$ for $t \geq 0$. This is the classic step response of a first-order LTI system asymptotically approaching unity.
9. B — Express $-16 = 16 \cdot e^{(j\pi)}$, so the square roots are $\pm 4 \cdot e^{(j\pi/2)} = \pm 4j$. The principal root with positive imaginary part is 4j. Complex roots always come in pairs symmetric about the origin.
10. A — Compute the curl: $\nabla \times F = (0, 0, -2)$. For the disk of area $\pi(2)^2 = 4\pi$ in the xy-plane with normal $+\hat{k}$, the surface integral becomes $(-2) \cdot 4\pi = -8\pi$. Stokes' theorem converts the difficult closed line integral into a simpler surface integral.
11. C — The polar curve $r = 2 \cdot \cos\theta$ traces a circle of radius 1 centered at (1, 0). Its area is $\pi \cdot (1)^2 = \pi$. The transformation $r = 2a \cdot \cos\theta$ always produces a circle of radius a passing through the origin.
12. D — Characteristic equation $r^2 + 6r + 13 = 0$ has discriminant $36 - 52 = -16$, yielding complex roots $r = -3 \pm 2j$. For complex roots $a \pm bj$ the solution takes the form $e^{(ax)} \cdot [C_1 \cdot \cos(bx) + C_2 \cdot \sin(bx)]$ — the classic underdamped second-order response. The real part drives exponential decay; the imaginary part drives oscillation.
13. B — The Maclaurin series of e^x is $\Sigma\, x^n/n!$. Truncating through the x^3 term: $1 + x + x^2/2! + x^3/3! = 1 + x + x^2/2 + x^3/6$. This series underlies essentially every exponential approximation in transient circuit and signal analysis.
14. A — Binomial probability: $P(X = 3) = C(5, 3) \cdot (0.5)^3 \cdot (0.5)^2 = 10 \cdot (1/32) = 5/16$. The five trials are independent and identically distributed with $p = 0.5$. Binomial calculations underpin reliability and quality-control statistics.

15. C — Variance of a sum: $Var(X + Y) = Var(X) + Var(Y) + 2 \cdot Cov(X, Y) = 4 + 9 + 2(3) = 19$. Independence would zero the covariance term; correlated variables require it explicitly. This identity generalizes to any linear combination of random variables.
16. C — For a normal distribution, the 95th percentile corresponds to $z \approx 1.645$. Applying $X = \mu + z \cdot \sigma = 50 + 1.645 \cdot 10 \approx 66.45$. The z-value 1.645 (one-sided 95%) is a standard reference for one-tailed hypothesis testing.
17. D — Probability of two red balls drawn without replacement: $P = (3/10) \cdot (2/9) = 6/90 = 1/15$. The second probability is conditional on the first draw being red, reducing both numerator and denominator. Without-replacement problems require multiplying successive conditional probabilities.
18. B — The NSPE Code permits paid expert testimony provided the engineer maintains technical objectivity and discloses the employment relationship to the court and all parties. Disclosure satisfies the conflict-of-interest provisions while preserving the engineer's freedom to provide professional opinion. Outright refusal of the role is not required.
19. A — NSPE Canon 1 makes public safety paramount, overriding any financial incentive offered by an employer. The engineer must refuse the bonus and complete the required inspections regardless of the schedule impact. Compromising safety jeopardizes both the engineer's license and public welfare.
20. D — Engineers have a duty to maintain technical accuracy and prevent unsafe outcomes. The proper response combines direct communication with the colleague, documentation of the error, and verification that the correction is implemented before construction proceeds. Silent correction or passive waiting allows risk to persist unchecked.
21. B — NSPE Section II.4 requires engineers to disclose to all affected parties in writing any circumstance that could be construed as a conflict of interest, including service to competing firms. Silent multi-client representation breaches the fiduciary duty to each client. Written disclosure is the cleanest protective practice.
22. A — Net present worth: $NPW = -100{,}000 + 40{,}000 \cdot 2.4869 = -100{,}000 + 99{,}476 = -\$524$. The slight negative result indicates the project just fails to meet the 10% MARR. NPW magnitudes near zero require careful interpretation against rounding error in the (P/A) factor.
23. C — In present-worth analysis with equal study periods, the alternative with the higher PW is preferred. Alternative A's $50,000 exceeds B's $48,000 by $2,000, so A is chosen. Direct PW comparison applies only when the alternatives share an identical service life.
24. D — Simple payback period: $10,000/$2,500 = 4.0 years. Simple payback ignores both the time value of money and any cash flows beyond the payback point. It nonetheless remains a widely used screening criterion in capital budgeting.
25. D — Annual payment: $A = P \cdot (A/P, 5\%, 10) = 500{,}000 \cdot 0.1295 = \$64{,}750$. The capital recovery factor converts present principal into an equivalent uniform annual cash flow. Loan amortization is the most common engineering-economy application most professionals encounter directly.
26. A — Straight-line depreciation per year: $(80{,}000 - 20{,}000)/5 = \$12{,}000$. After three years: $80{,}000 - 3 \cdot 12{,}000 = \$44{,}000$. Straight-line produces linear book-value decline, simplifying forecasting compared to MACRS or declining-balance methods.
27. C — In an n-type semiconductor, donor-supplied electrons in the conduction band shift the Fermi level upward toward the conduction band edge. The shift magnitude increases with doping concentration. The opposite shift occurs in p-type material, where the Fermi level moves toward the valence band edge.

28. B — Copper's temperature coefficient of resistance at 20°C is approximately +0.00393 per °C. Conductors exhibit positive TCR (resistance rises with temperature) because phonon scattering increases with thermal energy. This value forms the basis for resistance-temperature detectors (RTDs) used throughout industrial temperature measurement.
29. A — Conductivity: $\sigma = q \cdot n \cdot \mu = (1.6\times10^{-19})\cdot(10^{16})\cdot(1{,}350) = 2.16$ S/cm. Carrier density and mobility multiply to give the bulk electrical response, with the elementary charge providing the per-carrier scaling. This product is the fundamental relationship for semiconductor conductivity.
30. B — Ferroelectric materials exhibit spontaneous electric polarization that can be reversed by an applied electric field, producing a hysteresis loop analogous to ferromagnetism. This bistability enables non-volatile memory devices (FeRAM) and high-permittivity capacitor dielectrics.
31. C — Terminal voltage equals source EMF minus internal resistance drop: $V_{terminal} = 12 - 6\cdot0.5 = 9$ V. Internal resistance reduces deliverable voltage as load current increases. This effect ultimately limits the maximum power transferrable from any real voltage source.
32. A — Time constant $\tau = RC = 1{,}000\cdot200\times10^{-6} = 0.2$ s. Solving $V_C(t) = 50\cdot e^{(-t/\tau)} = 10$ gives $t = \tau\cdot\ln(5) = 0.2\cdot1.609 \approx 0.322$ s. Exponential discharge follows the same form for any first-order RC network.
33. B — The upper branch sums $R_2 + R_3 = 6\ \Omega$. Parallel with the lower 3 Ω branch: $(6\cdot3)/(6 + 3) = 2\ \Omega$. Adding the series R_1: $6 + 2 = 8\ \Omega$. Systematic reduction of nested series-parallel groups is the standard technique for ladder networks.
34. B — Inductive reactance: $X_L = 2\pi\cdot60\cdot0.1 \approx 37.7\ \Omega$. Impedance magnitude: $|Z| = \sqrt{30^2 + 37.7^2} \approx 48.2\ \Omega$. Current: $|I| = 240/48.2 \approx 5.0$ A. AC steady-state current in a series RL combines resistive and reactive components through the impedance triangle.
35. D — Y-connected systems satisfy $V_{LL} = \sqrt{3}\cdot V_{phase}$. With $V_{phase} = 277$ V: $V_{LL} = \sqrt{3}\cdot277 \approx 480$ V. This is exactly the standard US 480Y/277 V commercial distribution voltage relationship.
36. C — Series LC resonance: $f_0 = 1/(2\pi\cdot\sqrt{LC}) = 1/(2\pi\cdot\sqrt{0.1\cdot10^{-5}}) = 1/(2\pi\cdot10^{-3}) \approx 159$ Hz. At resonance, inductive and capacitive reactances cancel exactly. This frequency is the natural oscillation frequency of the LC tank.
37. A — In standard cosine-reference phasor notation, $v(t) = V_p\cdot\cos(\omega t + \varphi)$ corresponds to $V_p\angle\varphi$. Therefore $100\cdot\cos(\omega t + 30°)$ maps to $100\angle30°$. Phasor conversion preserves magnitude and phase while removing the time variable for AC steady-state analysis.
38. D — Inverting amplifier gain: $A_v = -R_f/R_{in} = -100/5 = -20$. The negative sign indicates 180° phase inversion between input and output. The op-amp's high open-loop gain makes the closed-loop gain depend only on the external resistor ratio.
39. C — At series resonance, the magnitudes of the inductor and capacitor voltages each equal Q times the source voltage. With $Q = 10$ and $V_s = 10$ V (rms): $V_L = 10\cdot10 = 100$ V. High-Q circuits produce dramatic voltage magnification at resonance, requiring careful component voltage ratings.
40. D — Series impedances add: $Z_{total} = (10 + 20) + j(10 - 5) = 30 + j5\ \Omega$. Magnitude: $|Z| = \sqrt{900 + 25} = \sqrt{925} \approx 30.4\ \Omega$. Reactive parts may add or partially cancel depending on the inductive versus capacitive components.
41. B — In the ABCD parameter set defined by $V_1 = A\cdot V_2 - B\cdot I_2$, setting $I_2 = 0$ (output open-circuited) yields $A = V_1/V_2$. This is the open-circuit voltage transfer ratio of the two-port network. ABCD parameters allow modular composition of cascaded networks through matrix multiplication.

42. D— An ideal voltage source fixes its terminal voltage at exactly its source value regardless of any current source connected in parallel. The current source merely adjusts its own contribution to satisfy KCL. The terminal voltage is therefore 10 V, set entirely by the voltage source.

43. C — Norton current equals the short-circuit current: $I_N = I_{short} = 3$ A. Norton resistance equals open-circuit voltage divided by short-circuit current: $R_N = 12/3 = 4\ \Omega$. This two-measurement technique fully characterizes any linear black-box network at a port.
44. A — Apply the Final Value Theorem to a step input of magnitude V: $y_{ss} = V \cdot H(0) = V \cdot (K/a)$. The DC gain H(0) determines the steady-state response to constant inputs. This relationship is the basis for DC analysis of feedback control systems.
45. D — Complex-conjugate poles inside the unit circle produce a stable system with oscillating yet exponentially decaying impulse response. The radius $0.9 < 1$ guarantees stability; the imaginary component drives the oscillation. This response shape is typical of underdamped digital filter behavior.
46. B — The Laplace transform pair $L\{t^n \cdot u(t)\} = n!/s^{(n+1)}$ gives $L\{t^2\} = 2!/s^3 = 2/s^3$. This pair is fundamental for analyzing parabolic-ramp inputs in control systems. The factorial in the numerator is easily forgotten and is a common source of errors.
47. A — DC gain equals H(0) for stable systems. With $H(s) = 1/(s + 2)$: $H(0) = 1/2$. Equivalently, $\int_0^\infty e^{(-2t)}\, dt = 1/2$ confirms the steady-state step response. DC gain links the time-domain and frequency-domain views of the system.
48. C — System order equals the degree of the denominator polynomial after expansion: $(s + 1)(s + 2)(s + 4)$ is cubic, so the order is 3. The zero at $s = -3$ does not affect order. Order determines the number of state variables and the maximum number of poles in the realization.
49. D — In the state-space form $\dot{x} = Ax + Bu$ with output $y = Cx + Du$, A is the state (or system) matrix and embeds the system dynamics. Its eigenvalues equal the system poles. Pole-placement controllers operate by shifting these eigenvalues to desired closed-loop locations.
50. B — Sampled at 1.5 kHz, the Nyquist frequency is 750 Hz, so a 1 kHz tone aliases. The folded frequency is $|1{,}000 - 1{,}500| = 500$ Hz. Anti-aliasing filters must attenuate content above the Nyquist frequency before the sampler.
51. A — DFT frequency resolution: $\Delta f = f_s/N = 8{,}000/1{,}024 = 7.8125$ Hz. Higher sampling rates or longer transforms give finer resolution at the cost of increased computation. This trade-off between resolution and processing burden guides FFT design.
52. C — The z-transform of x[n] is the polynomial in z^{-1} formed from the sample sequence: $1 + 2 \cdot z^{-1} - z^{-2}$. Each unit delay corresponds to multiplication by z^{-1}. The z-domain representation simplifies digital filter and discrete-system analysis.
53. D — Windowing tapers the analyzed segment at its edges, reducing the spectral leakage that arises when arbitrary truncation introduces high-frequency content. The Hamming window achieves a good balance of main-lobe width and side-lobe suppression. Window selection trades resolution against leakage in any practical FFT analysis.
54. B — Decimation by factor M produces a lower-rate sequence by keeping every M-th sample of the original. The effective sampling rate becomes f_s/M. Anti-aliasing pre-filtering is required because the new Nyquist frequency drops to $f_s/(2M)$.
55. C — A causal FIR filter with N taps (coefficients) produces an impulse response exactly N samples long. The output decays to zero N samples after the input pulse ends. The finite length guarantees absolute stability and enables linear phase realization.
56. A — Active region: $I_C = \beta \cdot I_B = 100 \cdot (50 \times 10^{-6}) = 5$ mA. The current gain β multiplies base current into collector current. Active-region operation (B-E forward, B-C reverse biased) is the foundation of BJT amplification.

57. A — MOSFET saturation drain current: $I_D = (1/2)\cdot\mu_n\cdot C_{ox}\cdot(W/L)\cdot(V_{GS} - V_T)^2 = 0.5\cdot 2\cdot(2)^2 = 4$ mA. The square-law dependence on overdrive voltage ($V_{GS} - V_T$) is the defining feature of saturation operation. Doubling overdrive quadruples the drain current.
58. B — Source degeneration introduces local negative feedback ($1 + g_m\cdot R_S$ in the denominator of the gain expression), reducing small-signal voltage gain. The trade-off improves linearity, increases bandwidth, and stabilizes the bias point against device-parameter variation. Bypass capacitors restore full gain at signal frequencies while preserving DC degeneration.
59. C — The bottom of the common-mode input range is limited by the voltage headroom required across the tail current source plus the V_{GS} (or V_{BE}) of the input transistors. Insufficient headroom forces the tail source out of its operating region. Rail-to-rail input designs use complementary input stages to extend this range.
60. D — Schottky diodes form their junction between a metal and an n-type semiconductor, producing a lower forward voltage (≈ 0.3 V) and dramatically faster switching due to the absence of minority carrier storage. These properties make Schottky diodes essential in high-frequency rectifiers and switch-mode power converters.
61. B — Op-amp gain-bandwidth product is essentially constant for the device. In unity-gain configuration, the closed-loop bandwidth equals the open-loop unity-gain frequency (the GBW). This relationship determines maximum signal bandwidth at any closed-loop gain via $BW = GBW/A_{CL}$.
62. C — Wien-bridge oscillator frequency: $f = 1/(2\pi\cdot R\cdot C) = 1/(2\pi\cdot 10^4\cdot 16\times 10^{-9}) \approx 995$ Hz. The bridge's frequency-selective feedback produces low-distortion sinusoidal oscillation. RC oscillators dominate audio-frequency signal generation.
63. A — Buck converter steady-state voltage transfer in continuous conduction mode: $V_{out} = D\cdot V_{in}$, where D is the switch duty cycle. The relationship follows from inductor volt-second balance over one switching period. Duty-cycle control provides direct, linear regulation of the output voltage.
64. D — Synchronous speed: $n_s = 120\cdot f/P = 120\cdot 60/6 = 1{,}200$ rpm. Synchronous machines lock to this frequency-determined speed regardless of load. Pole count selection trades synchronous speed against motor physical size.
65. B — Conductor losses scale as I^2 at fixed R, and current is inversely proportional to voltage for constant power. Halving the loss requires reducing I by $\sqrt{2}$, which means multiplying voltage by $\sqrt{2}$. This relationship is the basic justification for high-voltage transmission.
66. A — Synchronous speed: $n_s = 120\cdot 60/4 = 1{,}800$ rpm. Slip: $s = (1{,}800 - 1{,}750)/1{,}800 \approx 2.78\%$. Induction motors operate with small positive slip under load, and slip grows toward the pull-out value as load torque approaches breakdown.
67. C — Line current: $I_L = S/(\sqrt{3}\cdot V_{LL}) = 30{,}000/(\sqrt{3}\cdot 480) \approx 36.1$ A. The $\sqrt{3}$ factor appears in every three-phase apparent-power calculation. Power factor does not affect line current magnitude — only the real-power component.
68. D — At full load and unity PF: total losses = $50{,}000/0.97 - 50{,}000 \approx 1{,}547$ W. Subtracting the 500 W core losses leaves copper losses ≈ 1,047 W. Efficiency analysis separates fixed (frequency-dependent) core losses from load-dependent copper losses.
69. B — Original reactive demand: $Q_{old} = P\cdot\tan(\arccos 0.7) \approx 204$ kVAR. After 140 kVAR compensation: $Q_{new} = 64$ kVAR. New $PF = P/\sqrt{P^2 + Q^2} = 200/\sqrt{200^2 + 64^2} \approx 0.95$. Capacitor banks correct power factor by supplying local reactive power, freeing utility capacity.

70. C — Real power: $P = S \cdot PF = 10 \cdot 0.85 = 8.5$ kW. The remaining 5.27 kVAR is reactive power that does no useful work but increases apparent demand. Improving power factor reduces utility billing penalties and frees system capacity.
71. D — In a DC shunt motor, speed $n = (V - I_a \cdot R_a)/(K \cdot \Phi)$, which is inversely proportional to flux. Increasing field current raises Φ and therefore reduces speed. Field weakening (reducing field current) is the standard method for operating above base speed.
72. A — Secondary full-load current: $I_{sec} = S/V_{sec} = 100{,}000/240 \approx 417$ A. The low-voltage side always carries proportionally higher current. Conductor sizing on the secondary side must accommodate this large current.
73. B — Magnetic field around a long straight wire: $B = \mu_0 \cdot I/(2\pi r) = (4\pi\times10^{-7})\cdot 50/(2\pi\cdot 0.1) = 10^{-4}$ T $= 100$ µT. The field falls off as 1/r perpendicular to the wire. This formula is the foundation of magnetostatic field calculations.
74. C — Average Poynting magnitude for a plane wave in free space: $S_{avg} = E_0^2/(2\eta_0) = (100)^2/(2\cdot 377) \approx 13.3$ W/m². The factor of 2 in the denominator arises from time-averaging the squared sinusoidal field. Free-space impedance $\eta_0 \approx 377\ \Omega$ is a fundamental constant of electromagnetism.
75. A — Reflection coefficient: $\Gamma = (Z_L - Z_0)/(Z_L + Z_0) = (100 - 50)/(100 + 50) = 1/3$. Positive Γ indicates the load impedance exceeds the line's characteristic impedance. Reflection coefficient magnitude determines voltage standing wave ratio via $VSWR = (1 + |\Gamma|)/(1 - |\Gamma|)$.
76. B — Skin depth $\delta = \sqrt{2/(\omega\mu\sigma)} \propto 1/\sqrt{f}$. Higher frequencies confine current to a thinner surface layer, increasing the effective AC resistance. This effect drives the use of stranded Litz wire or hollow conductors at high frequencies.
77. D — Routh array: row s^3 [1, 50], row s^2 [15, K], row s^1 [(750 − K)/15, 0], row s^0 [K]. All first-column entries must be positive: $K < 750$ and $K > 0$, so the maximum K for stability is 750. Routh-Hurwitz analysis locates stability boundaries without computing characteristic roots.
78. D — A PI controller $K_p + K_i/s$ is dominated at low frequencies by $K_i/(j\omega)$, whose magnitude varies as $1/\omega$. On a Bode plot this gives a slope of −20 dB/decade. The slope flattens to 0 dB/decade above the corner frequency K_i/K_p.
79. C — Both stability margins are positive (PM > 0°, GM > 0 dB), indicating closed-loop stability. PM = 45° comfortably exceeds the typical adequacy threshold of 30°, and GM = 6 dB provides reasonable gain headroom against parameter variation. These values represent a well-designed control loop.
80. A — A diagonal A matrix decouples the state equations: each state variable evolves as $\dot{x}_i = a_{ii} \cdot x_i +$ (input terms) independently of the other states. This canonical form simplifies analysis and is achievable for any non-defective A via similarity transformation. The diagonal entries are the eigenvalues directly.
81. B — The Bode phase curve crosses −90° at $\omega = 10$ rad/s, which is the signature frequency where the second-order system's poles lie (ω_n). The magnitude plot shows a slight peak near this frequency, consistent with light underdamping. Reading ω_n from Bode plots is a routine system-identification technique.
82. C — Root locus branches crossing the imaginary axis correspond to closed-loop poles with zero real part: marginal stability with sustained sinusoidal oscillation. This crossing identifies the critical gain at which stability is lost. Beyond this gain the closed-loop system becomes unstable.
83. A — Multiplying the loop gain by K adds $20\cdot\log_{10}(K)$ dB to the magnitude at every frequency, shifting the entire Bode magnitude curve upward by that fixed amount. The phase plot is unaffected

by pure gain scaling. This shift is used to set the gain crossover frequency precisely during loop shaping.

84. D — The AM modulation index is defined as m = A_m/A_c, the ratio of peak message amplitude to unmodulated carrier amplitude. Values $m \leq 1$ are required to avoid overmodulation and envelope distortion. The index sets the depth of amplitude variation in the modulated waveform.
85. B — 256-QAM uses $256 = 2^8$ constellation points, so each symbol conveys $\log_2(256) = 8$ bits. Higher-order QAM increases spectral efficiency proportionally but demands higher SNR for the same bit error rate. Adaptive modulation matches order to channel conditions.
86. C — Shannon capacity: $C = B \cdot \log_2(1 + SNR) = 10{,}000 \cdot \log_2(1{,}001) \approx 10{,}000 \cdot 9.97 \approx 99.7$ kbps ≈ 100 kbps. Capacity grows logarithmically with SNR but linearly with bandwidth. Practical systems achieve a fraction of this theoretical bound.
87. D — Increasing the bit rate at fixed total signal power lowers the energy per bit, since E_b = P_signal·T_b. Lower E_b/N_0 degrades the bit error rate for any modulation scheme. The trade-off between throughput and reliability is captured exactly by Shannon's bound.
88. A — The noise figure F quantifies the SNR degradation introduced by a stage: F = (SNR_in)/(SNR_out), or in dB, NF = SNR_in,dB − SNR_out,dB. Lower noise figure preserves more of the input SNR. Cascade noise figure follows Friis' formula, with the first stage dominating overall system noise performance.
89. B — TCP's sliding window allows the sender to transmit multiple unacknowledged segments up to the window size, dramatically improving throughput on networks with non-zero round-trip time. Without windowing, throughput would be limited to one segment per RTT. The window size is dynamically adjusted by flow control and congestion control mechanisms.
90. D — The 7-byte Ethernet preamble (alternating 10101010 bytes) followed by the 1-byte Start Frame Delimiter provides the receiver with a known pattern for clock recovery and frame synchronization. Without it the receiver cannot lock onto bit timing. Modern Gigabit Ethernet uses 8B/10B coding but retains an equivalent synchronization function.
91. A — IPv6 addresses are 128 bits long, providing $2^{128} \approx 3.4\times10^{38}$ possible addresses. The vastly larger address space relative to IPv4's 32 bits eliminates address-exhaustion concerns for the foreseeable future. IPv6 also introduces a simplified header format and built-in autoconfiguration.
92. D — VLANs operate at the Data Link layer (Layer 2) by tagging Ethernet frames with VLAN identifiers (typically using IEEE 802.1Q). The tagging logically separates broadcast domains across the same physical infrastructure. VLAN routing between separate VLANs requires Layer 3 functionality.
93. C — Convert 0x2A by expanding each hex digit to 4 binary bits: 2 = 0010 and A = 10 = 1010. Concatenating yields 0010 1010 = 00101010. This bit pattern also equals decimal 42.
94. A — Apply the distributive and complementarity laws: $A\cdot B' + A\cdot B = A\cdot(B' + B) = A\cdot 1 = A$. The OR of a variable with its complement always equals 1, which absorbs the B dependence entirely. This is one of the canonical Boolean simplification identities.
95. C — De Morgan's theorem states $(A\cdot B)' = A' + B'$ and dually $(A + B)' = A'\cdot B'$. Negation distributes by inverting each operand and swapping AND with OR. These dual identities are the foundation of NAND/NOR universal logic and many circuit transformations.
96. B — A 3-to-8 decoder asserts exactly one output corresponding to the binary value of the input. Input $101_2 = 5$, so output Y_5 goes HIGH while all others remain LOW. Decoders are central to memory address selection and instruction decoding in CPU architectures.

97. A — A 4-bit counter has modulus $2^4 = 16$, rolling over to 0000 after every 16 clock pulses. After 17 pulses: 17 mod 16 = 1, so the count is 0001. Counter modulus determines its application as frequency divider, sequence generator, or address counter.
98. D — In modern deep-submicron CMOS, both subthreshold drain leakage and gate-oxide tunneling leakage dominate static power dissipation. Switching transitions account for active (dynamic) power, which is separate. Process scaling has driven leakage to a significant fraction of total chip power, motivating power-gating and high-Vt design techniques.
99. C — Synchronous sequential machines drive all flip-flops from a common clock signal, so state changes occur only on the active clock edge. Between edges the state is stable while combinational logic settles. Synchronous design enormously simplifies timing analysis compared to asynchronous alternatives.
100. B — In a CMOS inverter, V_in = V_DD turns the NMOS on (pulling output to ground) and the PMOS off (blocking the supply path). The output is therefore driven to 0 V. The complementary pull-up/pull-down structure is the defining feature of CMOS logic and gives near-zero static current.
101. C — A memory of 256 K = 2^{18} = 262,144 addressable locations requires 18 address lines to uniquely select each location. The 8-bit word width is supplied by 8 separate data lines independent of the address. Address-line count directly limits the maximum addressable capacity.
102. B — In the MESI cache coherence protocol, the M (Modified) state indicates a cache line that has been written to locally but not yet written back to main memory. The line is therefore "dirty," meaning it differs from main memory and must be written back before another cache can hold a valid copy.
103. D — Data hazards arise when a pipeline instruction needs a result that has not yet been written back. Forwarding (bypassing) routes the computed result from the EX or MEM pipeline stage directly to the dependent instruction's input, avoiding stalls. Hardware forwarding is universal in modern in-order pipelines.
104. A — A 4 KB page contains 2^{12} bytes, so 12 bits of the virtual address are required to address any byte within a page. The remaining $32 - 12 = 20$ bits form the virtual page number used for translation. Page size selection trades fragmentation against page-table size.
105. C — Conditional branches create control hazards because the branch outcome is unknown until the instruction reaches a later pipeline stage. Branch prediction speculatively continues fetching from the predicted target, accepting a flush penalty on misprediction. Modern processors achieve prediction accuracy often exceeding 95%.
106. B — At 1 GHz clock and 1 instruction-per-cycle peak throughput: 10^9 cycles/s × 1 IPC = 10^9 instructions/s = 1 GIPS. Real workloads achieve a fraction of this peak due to pipeline stalls and cache misses. Wider-issue superscalar designs can exceed 1 IPC by issuing multiple instructions per cycle.
107. A — The Liskov Substitution Principle requires that derived-class objects can replace base-class objects anywhere in the program without altering correctness. Violating LSP indicates a flawed inheritance hierarchy that introduces subtle bugs. LSP is the "L" in the SOLID design principles.
108. D — Technical debt captures the future cost of choosing a quick or easy implementation today instead of a more robust one that would have required more time. Like financial debt, technical debt accrues "interest" through harder maintenance and slower future development. Periodic refactoring pays down accumulated debt.

109. C — The Singleton pattern restricts a class to a single instance and provides a global point of access to it. Typical uses include configuration managers, logging facilities, and connection pools. Singletons must be designed carefully to avoid hidden coupling and to remain testable.

110. A — Git rebase reapplies a sequence of commits onto a different base commit, producing a linear history without merge commits. This contrasts with merge, which preserves both branch histories joined by a merge commit. Rebase rewrites history and should not be used on commits already pushed to shared branches.