PRACTICE EXAM 14: FE ELECTRICAL AND COMPUTER SIMULATION (110 QUESTIONS)

Time allotted: 5 hours 20 minutes

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

1. Evaluate the limit $\lim(x \to 0)\ [(1 - \cos(2x))/x^2]$.

A. 0

B. 1

C. ∞ (limit does not exist)

D. 2

2. For the matrix $A = [[2, 0, 1], [-1, 3, 0], [0, 1, 2]]$, the determinant is:

A. 11

B. 12

C. 5

D. 9

3. Solve the first-order linear ODE $dy/dx + 2y = 0$ subject to the initial condition $y(0) = 3$.

A. $y = 3 \cdot e^{(2x)}$

B. $y = 3 \cdot e^{(-2x)}$

C. $y = 3 \cdot \cos(2x)$

D. $y = 6 \cdot \sin(x)$

4. For the function $f(x) = x^3 - 6x^2 + 9x + 2$, the x-coordinate of the local maximum is:

A. $x = 3$

B. $x = 0$

C. $x = 1$

D. $x = 2$

5. What is the Laplace transform of $f(t) = \sin(at) \cdot u(t)$?

A. $a/(s^2 + a^2)$

B. $s/(s^2 + a^2)$

C. $1/(s - a)$

D. $a/(s^2 - a^2)$

6. For the complex number $z = 4 \cdot e^{(j\pi/6)}$, the value of z^2 in polar form is:

A. $16 \cdot e^{(j\pi/12)}$

B. $8 \cdot e^{(j\pi/3)}$

C. $4 \cdot e^{(j\pi/3)}$

D. $16 \cdot e^{(j\pi/3)}$

7. Evaluate the definite integral $\int_0^2 (x^2 + 1)\, dx$.

A. $7/3$

B. 14/3

C. 10/3

D. 8/3

8. Find the dot product of the vectors $a = (3, -2, 1)$ and $b = (2, 4, -1)$.

A. 9

B. 5

C. −3

D. 12

9. The infinite geometric series $\Sigma(n=0 \text{ to } \infty)\ (1/3)^n$ converges to:

A. 3/2

B. 3

C. 1

D. The series diverges

10. For the polar coordinates $(r, \theta) = (4, \pi/3)$, the equivalent rectangular coordinates (x, y) are:

A. $(2\sqrt{3}, 2)$

B. $(2, 2\sqrt{3})$

C. $(4, \pi/3)$

D. $(2, 2)$

11. Compute the partial derivative $\partial z/\partial y$ at the point $(1, 1)$ for the function $z = x^2 \cdot \ln(y) + e^{(xy)}$.

A. $1 + 2e$

B. $2 + e$

C. e

D. $1 + e$

12. What is the angle (in degrees) between the vectors $u = (1, 0, 0)$ and $v = (1, 1, 1)$?

A. 30°

B. 60°

C. 54.74°

D. 45°

13. For the second-order ODE $y'' - 6y' + 9y = 0$, the general solution is:

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

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

C. $y = C_1 \cdot \cos(3x) + C_2 \cdot \sin(3x)$

D. $y = C_1 \cdot e^{(3x)}$

14. For a Poisson distribution with rate parameter $\lambda = 3$, the probability of exactly 2 events occurring is approximately ($e^{(-3)} \approx 0.0498$):

A. 0.135

B. 0.224

C. 0.180

D. 0.299

15. A sample of $n = 25$ measurements has mean $\bar{x} = 100$ and sample standard deviation $s = 10$. Using $t_{(\alpha/2)} = 2.064$ ($df = 24$), the half-width of the 95% confidence interval for the population mean is:

A. 1.0

B. 2.064

C. 0.4

D. 4.13

16. For two independent random variables X and Y with E[X] = 5 and E[Y] = 3, the expected value of the product E[X·Y] equals:

A. 15

B. 8

C. 2

D. Cannot be determined without additional information

17. In a simple linear regression analysis, a coefficient of determination $R^2 = 0.64$ means:

A. The model predicts individual data points with 64% accuracy

B. The Pearson correlation coefficient between x and y is exactly 0.64

C. 64% of the total variance in the response variable is explained by the regression

D. The slope coefficient β_1 equals 0.64

18. An engineer is convinced that their employer's proposed product design poses a public safety hazard. After internal concerns have been raised and dismissed by management, the engineer's next step per the NSPE Code should be to:

A. Wait until a customer complaint forces management to reconsider

B. Notify the appropriate regulatory authorities and document the chain of internal communications

C. Resign immediately without further communication to avoid association

D. Implement the design but attach a personal disclaimer to all signed drawings

19. A licensed PE provides structural engineering services to a homeowner as a side project, completely separate from their primary employer's work. Under the NSPE Code, the PE must:

A. Disclose this outside engagement to the primary employer

B. Keep all outside work strictly confidential from the primary employer

C. Use the primary employer's company letterhead for the side project documents

D. Charge the same hourly rates as the primary employer would charge

20. During a public hearing on a proposed bridge replacement, a licensed PE provides paid expert testimony favoring one position. According to the NSPE Code, the testimony must:

A. Favor only the position that the paying party supports

B. Avoid mentioning any opposing technical viewpoints

C. Be objective and truthful, with prior disclosure of the financial interest

D. Use only data sets that were provided directly by the paying party

21. An engineer is contacted by a competitor's employee who offers to share confidential design information in exchange for a future job offer. Under the NSPE Code, the engineer should:

A. Accept the information if it would meaningfully accelerate a current project

B. Refuse to receive confidential information from the competitor's employee

C. Accept the information and consult with management afterward

D. Accept the offer if the competitor company has engaged in similar practices in the past

22. What is the future value of $5,000 invested for 10 years at 6% annual interest compounded annually?

A. $5,600

B. $8,000

C. $9,500

D. $8,954

23. An equipment purchase of $20,000 has annual operating costs of $3,000 and a salvage value of $5,000 at the end of 5 years. At MARR = 10%, using (A/P, 10%, 5) = 0.2638 and (A/F, 10%, 5) = 0.1638, the equivalent annual worth is:

A. −$7,457

B. −$3,000

C. −$5,400

D. +$7,457

24. A 30-year fixed-rate mortgage of $200,000 carries 4% APR compounded monthly. Using the monthly payment factor (A/P, 0.333%, 360) ≈ 0.004774, the monthly payment is approximately:

A. $556

B. $1,667

C. $666

D. $955

25. A break-even analysis between two manufacturing alternatives shows that the break-even point occurs at 5,000 units. For volumes above the break-even point:

A. Both alternatives have identical total cost

B. The alternative with lower fixed cost is always preferred

C. The alternative with the lower variable cost per unit is more economical

D. Both alternatives become unprofitable

26. The Internal Rate of Return (IRR) of a project is defined as the interest rate at which:

A. The Net Present Worth of the project equals zero

B. The Net Future Worth equals the initial investment value

C. The Effective Annual Rate of return reaches its maximum

D. The simple payback period is shortest

27. For an intrinsic semiconductor at thermal equilibrium, the law of mass action states that:

A. $n + p = N_D$ (donor concentration)

B. $n \cdot p = n_i^2$ (constant at a given temperature)

C. $n = N_A$ (acceptor concentration)

D. $p = 0$ under all conditions

28. In a typical n-type silicon semiconductor moderately doped at $N_D = 10^{16}$ cm^{-3}, the majority carrier (electron) concentration at room temperature is approximately:

A. 10^9 cm^{-3} (the intrinsic value)

B. 10^6 cm^{-3}

C. 10^{18} cm^{-3}

D. 10^{16} cm^{-3} (essentially equal to the dopant concentration)

29. The area enclosed by the B-H hysteresis loop of a magnetic material represents:

A. The remanent flux density of the material

B. The coercivity of the material

C. The energy dissipated per unit volume per cycle (hysteresis core loss)

D. The relative magnetic permeability

30. In a piezoelectric crystal, applied mechanical strain produces:

A. A proportional electric polarization (and conversely)

B. A measurable change in magnetic permeability

C. A change in optical refractive index only

D. Thermal expansion only

31. Two voltage sources V_1 = 10 V and V_2 = 15 V are connected in a series loop with opposing polarities through a single 5 Ω resistor. The magnitude of the current through the resistor is:

A. 5 A

B. 1 A

C. 3 A

D. 2 A

32. For a parallel RLC circuit at resonance driven by an ideal voltage source, the source current:

A. Increases without bound

B. Equals the inductor branch current alone

C. Equals zero in the ideal case

D. Is at a minimum, equal to the resistive branch current (V/R)

33. A 9 V battery is connected to a series combination of a 100 Ω resistor and a 200 Ω resistor. The voltage across the 200 Ω resistor is:

A. 6 V

B. 3 V

C. 4.5 V

D. 9 V

34. In a series RL circuit driven at frequency f, doubling f while keeping all component values constant will:

A. Halve the impedance magnitude

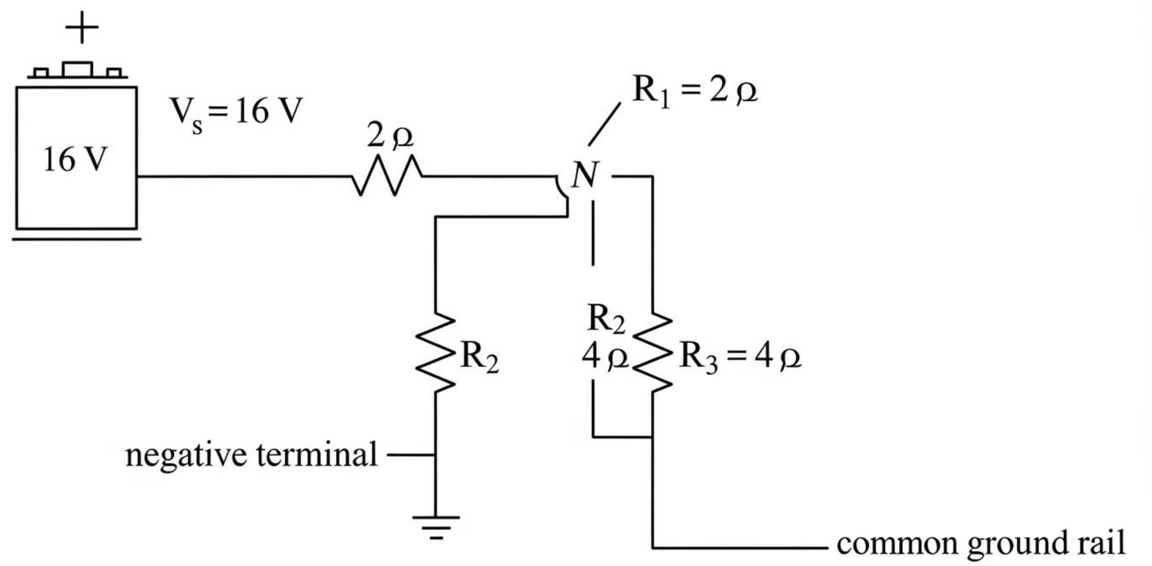
B. Exactly double the impedance magnitude

C. Increase the inductive reactance but leave the resistance unchanged

D. Not change any electrical quantity

35. For the series-parallel resistive network shown in the figure, the current through R_2 is:

Figure PQ-17



A. 3 A

B. 1.5 A

C. 2 A

D. 4 A

36. A four-arm Wheatstone bridge is balanced when:

A. All four arm resistances are equal in value

B. The products of opposite-arm resistances are equal: $R_1 \cdot R_4 = R_2 \cdot R_3$

C. The total network resistance reaches zero

D. The galvanometer indicates infinite resistance

37. For a parallel combination of two inductors $L_1 = 2$ mH and $L_2 = 6$ mH with no mutual coupling, the equivalent inductance is:

A. 8 mH

B. 4 mH

C. 12 mH

D. 1.5 mH

38. Two impedances $Z_1 = 6 + j8\ \Omega$ and $Z_2 = 6 - j8\ \Omega$ are connected in parallel. The magnitude of the equivalent impedance is:

A. 8.33 Ω

B. 6 Ω

C. 10 Ω

D. 5 Ω

39. In a series RLC circuit at resonance, the relationship between the magnitudes V_R, V_L, and V_C is:

A. V_R = V_L = V_C

B. V_R is much greater than V_L and V_C

C. V_L = V_C (they cancel in phasor sum), and V_R equals the source voltage magnitude

D. V_L and V_C are both zero at resonance

40. In an AC circuit, $v(t) = 100\cdot\cos(\omega t)$ V and $i(t) = 5\cdot\cos(\omega t - 30°)$ A. The average power dissipated is:

A. 250 W

B. 217 W

C. 500 W

D. 125 W

41. The Norton equivalent of a linear network is characterized by:

A. A voltage source V_N in parallel with R_N

B. A voltage source V_N in series with R_N

C. A current source I_N in parallel with R_N

D. A current source I_N in series with R_N

42. A first-order RC low-pass filter has R = 1 kΩ and C = 10 μF. With a 5 V step applied to the input at t = 0 (capacitor initially uncharged), the capacitor voltage at t = 5 ms is approximately:

A. 5 V

B. 3.16 V

C. 1.84 V

D. 1.97 V

43. An inductor L = 50 mH carries the current i(t) = 4·sin(100t) A. The peak voltage across the inductor is:

A. 20 V

B. 5 V

C. 50 V

D. 200 V

44. For the transfer function H(s) = (s + 2) / [(s + 1)(s + 3)], the system has:

A. 2 zeros and 2 poles

B. 1 zero and 2 poles

C. 1 zero and 1 pole

D. No zeros

45. A causal LTI system has impulse response $h(t)$ that decays to zero as $t \to \infty$ if and only if:

A. All zeros of $H(s)$ lie in the left-half plane

B. The DC gain of the system is positive

C. The system has at least one zero

D. All poles of $H(s)$ have negative real parts

46. Apply the Initial Value Theorem to $F(s) = (3s + 2)/(s^2 + 4s + 3)$. The value of $f(0^+)$ is:

A. 0

B. 3

C. 2/3

D. 1

47. The Fourier transform of a real, even continuous-time signal $x(t) = x(-t)$ is:

A. Purely imaginary and odd

B. Purely real and odd

C. Purely real and even

D. Complex-valued in general

48. For a continuous-time LTI system, when the input is the complex exponential x(t) = e^(j2t), the output is:

A. y(t) = H(j2)·e^(j2t), where H(j2) is the frequency response evaluated at ω = 2

B. y(t) = e^(j2t) only if the system is the identity

C. y(t) = 0 for any unstable system

D. y(t) depends explicitly on the system's memory length

49. The unit step response of a first-order LTI system with time constant τ = 2 s, evaluated at t = 4 s, equals approximately:

A. 0.500 (50%)

B. 1.000 (100%)

C. 0.632 (63.2%)

D. 0.865 (86.5%)

50. A discrete-time signal sampled at f_s = 16 kHz is analyzed with an N-point DFT. The frequency spacing between DFT bins is:

A. f_s/N = 16,000/N

B. f_s = 16 kHz

C. 1/N

D. 2·f_s

51. The discrete-time impulse response $h[n] = (0.5)^{n} \cdot u[n]$ corresponds to a system that is:

A. Unstable (response grows without bound)

B. Stable (response decays to zero) and causal

C. Anti-causal

D. Marginally stable on the unit circle

52. A 4-tap FIR filter with impulse response h[n] = {1, 1, 1, 1}/4 is:

A. A high-pass filter with a notch at DC

B. An all-pass filter with constant magnitude response

C. A low-pass filter with zeros at $z = -1$ and $z = \pm j$

D. A band-pass filter centered at $f_s/4$

53. For a digital filter, the steady-state magnitude response at angular frequency ω is computed by:

A. Setting $z = 0$ in $H(z)$

B. Differentiating $H(z)$ with respect to z

C. Solving for the poles of $H(z)$

D. Evaluating $|H(e^{j\omega})|$ for ω from 0 to 2π

54. For an N-point FFT of a real signal sampled at f_s, the largest frequency that can be represented unambiguously is:

A. The Nyquist frequency $f_s/2$

B. The sampling frequency f_s

C. N times the sampling frequency

D. Zero

55. The convolution sum $y[n] = \Sigma\, x[k]\cdot h[n - k]$ is the standard input-output relationship for:

A. A non-linear discrete-time system

B. An unstable discrete-time system only

C. A frequency-varying discrete-time filter only

D. Any discrete-time LTI system

56. In the hybrid-π small-signal BJT model, the parameter r_π is approximately:

A. The collector load resistance

B. The output impedance r_o of the transistor

C. β/g_m (the base-to-emitter small-signal input resistance)

D. The bulk semiconductor resistance of the transistor body

57. An NMOS MOSFET in saturation has $V_{GS} = 4$ V, threshold voltage $V_T = 1$ V, and conduction parameter $\mu_n \cdot C_{ox} \cdot (W/L) = 0.5$ mA/V². The drain current is:

A. 9 mA

B. 2.25 mA

C. 4.5 mA

D. 1.125 mA

58. A common-source NMOS amplifier with a source-bypass capacitor across R_S exhibits a small-signal voltage gain of approximately:

A. $A_v \approx -g_m \cdot R_D$ (full transconductance gain, no source degeneration)

B. $A_v \approx 1$ (voltage follower)

C. $A_v = \beta \cdot R_C$

D. $A_v = -R_S/R_D$

59. For an op-amp operating with negative feedback, the closed-loop output impedance is:

A. The open-loop output impedance R_{out}, unchanged by feedback

B. Approximately $R_{out}/(1 + A \cdot \beta)$, much smaller than the open-loop value

C. Infinite for any feedback configuration

D. Equal to the connected load impedance

60. A diode small-signal model at the operating point I_D = 2 mA at room temperature has dynamic resistance (r_d) of approximately:

A. 26 Ω

B. 52 Ω

C. 0.5 Ω

D. 13 Ω

61. In an emitter-follower (common-collector) BJT configuration, the small-signal voltage gain is:

A. Slightly less than 1 (no inversion)

B. Slightly less than −1 (inverted)

C. Approximately −β

D. Very large in magnitude (much greater than unity)

62. An op-amp integrator circuit has R = 10 kΩ at the input and C = 1 µF in the feedback path. The integration time constant is:

A. 100 µs

B. 1 s

C. 10 ms

D. 100 ms

63. A specified op-amp slew rate of 1 V/µs means the output voltage can change by at most:

A. 1 V in 1 second

B. 1 V in 1 microsecond

C. 1 mV in 1 microsecond

D. 1 µV in 1 second

64. A 60 Hz three-phase delta-connected source supplies a balanced delta-connected load. The line voltage is 480 V and the line current is 100 A. The phase current in each branch of the load is:

A. 100 A

B. 173 A

C. 50 A

D. 57.7 A

65. In a balanced four-wire Y-connected three-phase system, the current in the neutral conductor is:

A. Zero under fully balanced load conditions

B. Equal to the line current of any one phase

C. √3 times the line current

D. Equal to the phase voltage divided by the neutral wire impedance

66. In a power transformer, eddy-current losses within the iron core are minimized by:

A. Increasing the cross-sectional area of the core

B. Reducing the operating frequency below 60 Hz

C. Laminating the core (using stacks of thin insulated steel sheets)

D. Adding additional turns to the primary winding

67. The starting (locked-rotor) current drawn by a typical three-phase induction motor is approximately:

A. Equal to the rated full-load current

B. About half the full-load current

C. Equal to the no-load current

D. 5 to 7 times the rated full-load current

68. A synchronous motor operating with a leading power factor:

A. Draws more apparent power from the grid than at unity power factor

B. Supplies reactive power to the grid (operating as a synchronous condenser)

C. Has its rotor accelerating beyond synchronous speed

D. Cannot maintain stable steady-state operation

69. In a balanced three-phase circuit, the phase angle between the line-to-neutral voltage and the line current is 30° (lagging). The load power factor is:

A. 1.0

B. 0.5

C. 0.707

D. 0.866

70. Power utilities use high-voltage transmission lines primarily to:

A. Increase the kVA rating of the transformers

B. Reduce magnetic interference between adjacent lines

C. Reduce I^2R transmission losses by lowering the current carried for a given power level

D. Increase the mechanical safety factor of the conductor

71. The speed of a DC shunt motor is primarily controlled by:

A. Adjusting the field current to change the magnetic flux

B. Adjusting the armature winding resistance only

C. Changing the source frequency

D. Reversing the field winding polarity

72. For a three-phase induction motor under steady-state operation, increasing the mechanical load (torque demand) causes the slip to:

A. Decrease toward zero

B. Increase toward the breakdown (pull-out) slip

C. Remain constant regardless of load

D. Become negative

73. A uniform magnetic field B = 0.5 T points in the +z direction, and a current-carrying wire of 2 A flows in the +y direction. The force per unit length on the wire is:

A. 1 N/m in the −x direction

B. 1 N/m in the +x direction

C. 1 N/m in the −z direction

D. 0 (forces cancel)

74. A parallel-plate capacitor has plates of area 100 cm^2 separated by 2 mm of air ($\varepsilon_0 = 8.85\times10^{-12}$ F/m). The capacitance is approximately:

A. 442 pF

B. 88.5 pF

C. 0.443 nF

D. 44.3 pF

75. For a propagating electromagnetic wave, the Poynting vector $S = E \times H$ represents:

A. The instantaneous magnetic energy density

B. The voltage along the wave propagation path

C. The instantaneous power flux density (power per unit area) in the direction of propagation

D. The vector electric field intensity

76. For a long straight wire carrying current I, the magnetic field magnitude at perpendicular distance r from the wire is:

A. $B = \mu_0 \cdot I/(2\pi \cdot r)$

B. $B = \mu_0 \cdot I \cdot r$

C. $B = \mu_0/(I \cdot r^2)$

D. B = 0 anywhere outside the wire

77. For a second-order underdamped control system, the percent overshoot of the step response is determined by:

A. The natural frequency ω_n alone

B. The imaginary part of the poles alone

C. The damping ratio ζ alone ($PO = 100 \cdot \exp(-\pi\zeta/\sqrt{(1 - \zeta^2)})$)

D. The product ζ·ω_n

78. A second-order system has transfer function $H(s) = 100/(s^2 + 10s + 100)$. Its natural frequency ω_n and damping ratio ζ are:

A. ω_n = 10 rad/s, ζ = 1.0

B. ω_n = 100 rad/s, ζ = 0.05

C. ω_n = 10 rad/s, ζ = 0.05

D. ω_n = 10 rad/s, ζ = 0.5

79. In a PID-controlled feedback loop, increasing the integral gain K_i tends to:

A. Improve transient response speed while allowing finite steady-state error

B. Eliminate steady-state error to step inputs while potentially slowing transients and increasing overshoot

C. Have no effect on steady-state error

D. Render every closed-loop system unstable

80. For a state-space representation $\dot{x} = Ax + Bu$, $y = Cx + Du$, the system poles are determined by:

A. The eigenvalues of the matrix A

B. The eigenvalues of the matrix B

C. The transpose of the matrix D

D. The rank of the composite matrix [B AB]

81. A state-space system is said to be controllable when:

A. The system state can be driven from any initial state to any final state in finite time using a suitable input

B. The system output can be measured perfectly at all times

C. All eigenvalues of A have positive real parts

D. The input signal is restricted to a sinusoidal form

82. A lead compensator with transfer function $K \cdot (s + a)/(s + b)$, where $a < b$, provides:

A. Phase lag at all frequencies of interest

B. Reduced low-frequency open-loop gain

C. Positive phase shift (lead) in a range of frequencies, improving transient response

D. Pure integration of the error signal

83. For a unity-feedback control system with characteristic equation $s^3 + 4s^2 + 5s + K = 0$, the Routh-Hurwitz criterion gives the range of K for closed-loop stability as:

A. $0 < K < 5$

B. $0 < K < 4$

C. $K > 20$

D. $0 < K < 20$

84. For an FM signal with modulation index $\beta = 5$ and modulating frequency f_m = 1 kHz, the bandwidth predicted by Carson's rule is approximately:

A. 2 kHz

B. 12 kHz

C. 5 kHz

D. 10 kHz

85. The quantity E_b/N_0 (energy per bit divided by noise spectral density) in digital communication is:

A. A purely geometric measure of signal-to-noise ratio

B. The total transmit power of the system

C. The fundamental modulation-independent metric for comparing performance across digital modulation schemes

D. The channel bandwidth in Hz

86. Receiver thermal noise power follows P_noise = k·T·B (k = Boltzmann's constant, T = 290 K, B = 1 MHz). The noise power in dBm is approximately:

A. −114 dBm

B. −100 dBm

C. −120 dBm

D. 0 dBm

87. Frequency-Division Multiplexing (FDM) allows multiple signals to share a transmission channel by:

A. Assigning each signal a distinct time slot
B. Assigning each signal a distinct frequency band
C. Using orthogonal spreading codes for each signal
D. Sending all signals simultaneously on the same carrier frequency

88. In OFDM, orthogonality among subcarriers is maintained when:

A. All subcarriers have identical signal amplitudes
B. The cross-correlation between subcarriers is maximized
C. The subcarrier frequency separation is held constant regardless of symbol duration
D. The subcarrier spacing equals 1/T_s, where T_s is the OFDM symbol duration

89. The Domain Name System (DNS) primarily provides:

A. Encryption of network traffic between endpoints
B. Routing of packets between autonomous systems
C. Translation of human-readable domain names to IP addresses
D. Error correction within TCP transmissions

90. Applying the subnet mask 255.255.255.192 (/26) to a /24 network produces:

A. 2 subnets of 128 hosts each
B. 4 subnets of 62 usable hosts each
C. 8 subnets of 30 usable hosts each
D. 1 subnet of 254 usable hosts

91. The Hypertext Transfer Protocol (HTTP) operates at which layer of the OSI reference model?

A. Layer 3 (Network)
B. Layer 2 (Data Link)
C. Layer 4 (Transport)
D. Layer 7 (Application)

92. A Layer 2 Ethernet switch forwards a received frame based on:

A. The destination MAC address contained in the frame header
B. The source IP address of the frame
C. The TCP destination port number in the payload
D. A random choice among the available output ports

93. Convert the decimal value 47 to binary.

A. 101110_2
B. 110011_2
C. 101111_2
D. 110111_2

94. The Boolean expression $(A + B)\cdot(A + B')$ simplifies to:

A. B
B. A
C. $A\cdot B$
D. 1

95. In a synchronous sequential digital circuit, all flip-flop state changes occur:

A. On the active edge of a common clock signal

B. Whenever any combinational input changes value

C. Continuously, based on the input values

D. Asynchronously, with no dependence on any clock

96. An unsigned 16-bit register can hold decimal values in the range:

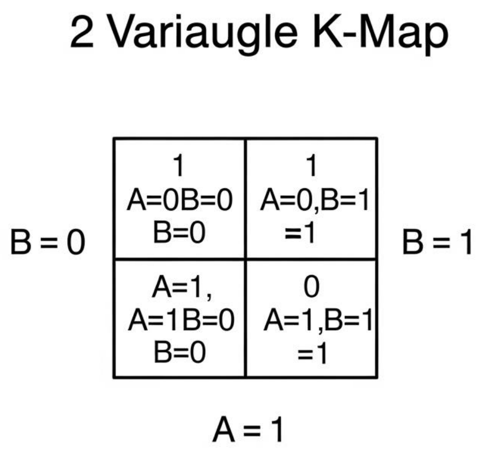
A. −32,768 to +32,767

B. −65,536 to +65,535

C. 0 to 32,767

D. 0 to 65,535

97. The minimized Boolean expression represented by the 2-variable K-map shown is:



Figuer PQ-18

A. A·B + A′

B. A + B

C. A′ + B

D. A·B′

98. A T-type flip-flop with input T = 1 at the active clock edge will:

A. Toggle the output (Q transitions from 0 to 1 or from 1 to 0)

B. Hold the previous output value unchanged

C. Set the output to 0

D. Set the output to 1

99. An n-input NAND gate produces a LOW (0) output only when:

A. Any one of the inputs is HIGH

B. All n inputs are simultaneously HIGH

C. All n inputs are LOW

D. Exactly half of the inputs are HIGH

100. In a standard CMOS NAND gate, the pull-up network (to V_DD) consists of:

A. A single PMOS transistor on its own

B. NMOS transistors connected in series

C. NMOS transistors connected in parallel

D. PMOS transistors connected in parallel

101. For an asynchronous (ripple) binary counter with N stages, the worst-case propagation delay before the count output is valid is approximately:

A. The delay of a single flip-flop

B. Twice the delay of a single flip-flop

C. N times the delay of a single flip-flop (cumulative ripple delay)

D. The delay of a single combinational gate only

102. The CPU instruction cycle (fetch-decode-execute) is best characterized as:

A. All three phases occurring strictly simultaneously in every processor

B. A sequence in which the CPU fetches an instruction, decodes it, then executes it — potentially overlapped across instructions in a pipelined processor

C. A sequence handled entirely by the operating system kernel

D. A concept that applies only to RISC architectures

103. Modern CPU caches achieve high hit rates primarily because:

A. Typical programs exhibit spatial and temporal locality of memory access

B. Memory access patterns in programs are essentially random

C. The cache stores only data that is being actively modified

D. Physical RAM has become large enough to make caching unnecessary

104. In a hypervisor-based virtualization environment:

A. Each virtual machine has direct hardware access with no isolation enforcement

B. The host operating system is bypassed entirely by every guest

C. The hypervisor mediates access to physical resources and provides isolation between virtual machines

D. Only single-tenant operation is technically supported

105. The MIPS (Million Instructions Per Second) performance metric:

A. Reliably compares CPU performance across architectures

B. Applies only to RISC processor designs

C. Is independent of instruction complexity

D. Is misleading when comparing processors with different instruction sets and instruction complexities

106. A 32-bit virtual address space provides:

A. Capacity for 32 simultaneously running processes

B. Up to $2^{32} \approx 4$ GB of addressable memory per process

C. Exactly 32 levels of page tables

D. Only 32 bytes of memory in total

107. In Agile software development, the daily stand-up meeting is intended to:

A. Briefly synchronize team members on yesterday's progress, today's plan, and any blockers

B. Replace all formal project documentation

C. Provide detailed line-by-line code reviews

D. Approve all new feature requests from stakeholders

108. The software development acronym CI/CD refers to:

A. Code Implementation and Compiler Design

B. Continuous Integration and Continuous Delivery (or Deployment)

C. Critical Issue and Change Documentation

D. Compatibility Integration and Cross-Platform Development

109. In object-oriented design, the principle "favor composition over inheritance" suggests:

A. Avoiding the use of any classes in the design

B. Using inheritance to model every relationship between objects

C. Building functionality by combining objects (has-a relationships) rather than always extending base classes (is-a relationships)

D. Restricting designs to procedural programming techniques

110. In a Git version control workflow, a commit represents:

A. A push of files to a remote repository server

B. A merge of two branches into one

C. A complete copy of an entire repository, including history

D. A snapshot of the project's tracked file state at a specific point in time

PRACTICE EXAM 14 – ANSWER KEY AND FULL ANSWER EXPLANATIONS

1. D — Apply the Taylor expansion $\cos(2x) \approx 1 - 2x^2$ for small x, so $1 - \cos(2x) \approx 2x^2$. Dividing by x^2 gives $(1 - \cos(2x))/x^2 \to 2$ as $x \to 0$. This limit is the second-derivative form of cosine at the origin and underlies many small-signal trigonometric approximations.
2. A — Cofactor expansion along row 1: det = 2·det([[3,0],[1,2]]) − 0 + 1·det([[−1,3],[0,1]]) = 2·6 + 1·(−1) = 11. Expanding along any row or column gives the same value, with row 1 chosen for the convenient zero entry. Cofactor expansion is the standard technique for 3×3 and larger determinants.
3. B — Separating variables yields $dy/y = -2\,dx$, integrating to $\ln|y| = -2x + C$, or $y = K\cdot e^{-2x}$. Applying $y(0) = 3$ gives $K = 3$, so $y = 3\cdot e^{-2x}$. This first-order linear decay equation appears throughout RC and RL transient analysis.
4. C — Take the first derivative: $f'(x) = 3x^2 - 12x + 9 = 3(x - 1)(x - 3)$, giving critical points at $x = 1$ and $x = 3$. The second derivative $f''(x) = 6x - 12$ is negative at $x = 1$, confirming a local maximum there. The other critical point at $x = 3$ is a local minimum.
5. A — The standard Laplace pair $L\{\sin(at)\cdot u(t)\} = a/(s^2 + a^2)$ is directly tabulated in the FE Reference Handbook. The companion pair for cosine is $s/(s^2 + a^2)$. Both are essential for analyzing sinusoidal sources in transient and AC circuit problems.
6. D — Squaring in polar form: $z^2 = 4^2\cdot e^{j\cdot 2\cdot \pi/6} = 16\cdot e^{j\pi/3}$. De Moivre's theorem gives this directly — magnitudes square and angles double. This shortcut applies for any integer power of a complex number expressed in polar form.
7. B — Antiderivative: $\int(x^2 + 1)\,dx = x^3/3 + x$. Evaluating from 0 to 2: $(8/3 + 2) - 0 = 8/3 + 6/3 = 14/3$. The Fundamental Theorem of Calculus reduces definite integrals to antiderivative differences at the endpoints.
8. C — The dot product is the sum of corresponding component products: $a\cdot b = 3\cdot 2 + (-2)\cdot 4 + 1\cdot(-1) = 6 - 8 - 1 = -3$. A negative result indicates the vectors point in opposing directions (obtuse angle between them). The dot product equals zero precisely when vectors are perpendicular.

9. A — For a geometric series Σr^n with $|r| < 1$, the sum is $S = a/(1 - r)$. Here $a = 1$ and $r = 1/3$, so $S = 1/(1 - 1/3) = 3/2$. Convergence requires $|r| < 1$; otherwise the series diverges.
10. B — Convert from polar to rectangular: $x = r \cdot \cos\theta = 4 \cdot \cos(\pi/3) = 4 \cdot (1/2) = 2$, and $y = r \cdot \sin\theta = 4 \cdot \sin(\pi/3) = 4 \cdot (\sqrt{3}/2) = 2\sqrt{3}$. The result $(2, 2\sqrt{3})$ corresponds to the point in the first quadrant at angle 60° from the positive x-axis.
11. D — Compute the partial with respect to y: $\partial z/\partial y = x^2 \cdot (1/y) + x \cdot e^{(xy)}$. Substituting $(x, y) = (1, 1)$: $1 \cdot 1 + 1 \cdot e^1 = 1 + e$. The chain rule produces the factor x in front of the exponential term.
12. C — Apply the dot-product angle formula: $\cos\theta = (u \cdot v)/(|u| \cdot |v|) = (1 \cdot 1 + 0 \cdot 1 + 0 \cdot 1)/(1 \cdot \sqrt{3}) = 1/\sqrt{3}$. Therefore $\theta = \arccos(1/\sqrt{3}) \approx 54.74°$. This angle appears as the body-diagonal angle of a unit cube and in many 3D geometry problems.
13. A — The characteristic equation $r^2 - 6r + 9 = (r - 3)^2 = 0$ has a repeated root $r = 3$. For a repeated root, the general solution carries an extra factor of x: $y = (C_1 + C_2 \cdot x) \cdot e^{(3x)}$. The standard two-exponential form would otherwise produce linearly dependent solutions.
14. B — Poisson probability: $P(X = k) = e^{(-\lambda)} \cdot \lambda^k/k!$. With $\lambda = 3$ and $k = 2$: $P(X = 2) = e^{(-3)} \cdot 9/2 \approx 0.0498 \cdot 4.5 \approx 0.224$. The Poisson distribution models the number of events in a fixed interval when events occur independently at a constant average rate.
15. D — The confidence-interval half-width is $t_{(\alpha/2)} \cdot s/\sqrt{n} = 2.064 \cdot 10/\sqrt{25} = 2.064 \cdot 10/5 = 4.128 \approx 4.13$. Larger samples shrink the standard error $s/\sqrt{n}$ and tighten the interval. Using the t-distribution rather than z is appropriate when the population standard deviation is unknown.
16. A — For independent random variables, the expected value of the product factors as $E[X \cdot Y] = E[X] \cdot E[Y] = 5 \cdot 3 = 15$. This factoring property requires independence; for correlated variables, the covariance term must be added. Independence is the key simplifying assumption.
17. C — The coefficient of determination R^2 quantifies the proportion of the total variance in the response variable that is explained by the regression model. $R^2 = 0.64$ indicates the model accounts for 64% of the variability in y. R^2 is neither the correlation coefficient (that is $\sqrt{R^2}$ with sign) nor the slope.
18. B — NSPE Canon 1 makes public safety paramount, so when internal channels fail to resolve a known safety concern, the engineer must report to appropriate regulatory authorities. Documentation of the internal communication chain protects the engineer and provides authorities with a complete record. The duty to the public overrides loyalty to an employer.
19. A — NSPE Section II.4.b requires engineers to disclose to their employers any outside engagements that could be construed as a conflict of interest. Disclosure preserves trust and allows the employer to identify potential conflicts before they materialize. Undisclosed moonlighting is one of the most common ethics-code violations.
20. C — NSPE Section III.3 requires that public testimony be objective, truthful, and inclusive of all relevant data, while Section II.4 requires disclosure of financial interests. Even paid testimony must remain technically honest, with the engineer's financial stake openly stated to the hearing body. The engineer is a professional witness, not a hired advocate.
21. B — Engineers must protect the confidential information of clients and employers and must not solicit or accept confidential information improperly obtained from competitors. Refusing the information closes off any appearance of corporate espionage. Accepting it would harm the competitor and expose the engineer to legal and ethical liability.
22. D — Future value: $F = P \cdot (1 + i)^n = 5{,}000 \cdot (1.06)^{10}$. Since $(1.06)^{10} \approx 1.7908$, the future value is approximately $5{,}000 \cdot 1.7908 \approx \$8{,}954$. Compound interest produces exponential growth, distinguishing it from simple-interest accumulation.

23. A — EAW = −20,000·(A/P) − 3,000 + 5,000·(A/F) = −20,000·0.2638 − 3,000 + 5,000·0.1638 = −5,276 − 3,000 + 819 = −$7,457. The negative result indicates a net annual cost; EAW analysis allows direct comparison of alternatives with different lives by expressing all cash flows as an equivalent annual figure.
24. D — Monthly payment: A = P·(A/P) = 200,000·0.004774 ≈ $955. The annuity factor converts the present principal into a uniform monthly cash flow over 360 periods. Mortgage amortization is the most common engineering-economy application most professionals encounter personally.
25. C — At the break-even point the total costs of two alternatives are equal. Above this volume, the alternative with the lower variable cost per unit accumulates lower incremental cost on every additional unit produced. Choice of method therefore depends on expected volume relative to the break-even point.
26. A — The Internal Rate of Return is defined as the discount rate at which the Net Present Worth of a project's cash flows equals zero. Projects with IRR exceeding the MARR are considered acceptable. IRR provides a return-rate criterion that is independent of project scale, though incremental analysis is needed for mutually exclusive comparisons.
27. B — The law of mass action states that the product of electron and hole concentrations equals the square of the intrinsic carrier concentration: $n \cdot p = n_i^2$, at thermal equilibrium for a given temperature. This relationship holds for both intrinsic and extrinsic semiconductors. It allows minority carrier concentration to be calculated from a known majority concentration.
28. D — For n-type silicon with $N_D = 10^{16}$ cm^{-3} at room temperature, donor atoms are essentially fully ionized and the intrinsic carrier concentration $n_i \approx 10^{10}$ cm^{-3} is negligible by comparison. The majority carrier concentration is therefore $n \approx N_D = 10^{16}$ cm^{-3}. This simple approximation is valid throughout the typical extrinsic operating regime.
29. C — The area enclosed by the B-H hysteresis loop represents the energy dissipated as heat per unit volume of magnetic material per AC cycle. This is the hysteresis component of core loss in transformers and inductors. Soft magnetic materials with narrow loops minimize this loss.
30. A — The piezoelectric effect couples mechanical strain to electric polarization in non-centrosymmetric crystals: applied strain produces proportional polarization, and applied electric field produces proportional strain (converse effect). Piezoelectric materials underpin transducers, ultrasound emitters, accelerometers, and precise frequency references.
31. B — Two opposing voltage sources produce a net loop voltage equal to their difference: $|15 - 10| = 5$ V. Ohm's law then gives the current magnitude: $I = 5/5 = 1$ A. KVL applied around the loop incorporates the source polarities to determine both magnitude and direction.
32. D — At parallel resonance, the inductive and capacitive admittances cancel, leaving only the resistive admittance 1/R. The parallel impedance reaches its maximum value (R), so the source current is minimized at V/R while reactive current circulates between L and C. Parallel-resonant tank circuits are the basis of band-stop filters and high-Q oscillator stages.
33. A — Voltage divider rule: $V_{200} = V \cdot (R_{200}/(R_{100} + R_{200})) = 9 \cdot (200/300) = 6$ V. The 200 Ω resistor receives two-thirds of the source voltage because it carries two-thirds of the total series resistance. Voltage division applies directly to any pure series resistor combination.
34. C — Inductive reactance $X_L = 2\pi \cdot f \cdot L$ scales linearly with frequency, so doubling f doubles X_L. Resistance R is frequency-independent. The total impedance magnitude $|Z| = \sqrt{(R^2 + X_L^2)}$ therefore increases but not by a simple factor of two.
35. C — Combine the parallel pair: $R_2 \parallel R_3 = (4 \cdot 4)/(4 + 4) = 2$ Ω. Total resistance: $R_1 + 2 = 4$ Ω; source current: 16/4 = 4 A. Node voltage at the parallel branches: 4·2 = 8 V, so $I_{R2} = 8/4 = 2$ A. Equal parallel resistors split the total branch current evenly.

36. B — Wheatstone bridge balance condition: the products of opposite-arm resistances are equal, $R_1 \cdot R_4 = R_2 \cdot R_3$. At balance, the midpoint potentials are equal and no current flows through the galvanometer. This null-detection property enables extremely precise resistance measurement.
37. D — Parallel inductors with no mutual coupling combine like parallel resistors: L_parallel = $(L_1 \cdot L_2)/(L_1 + L_2)$ = (2·6)/(2 + 6) = 1.5 mH. The reciprocal rule 1/L_eq = $1/L_1 + 1/L_2$ gives the same answer. Parallel combination always yields lower inductance than the smallest individual inductor.
38. A — Z_eq = $(Z_1 \cdot Z_2)/(Z_1 + Z_2)$. Numerator: (6 + j8)(6 − j8) = 36 + 64 = 100. Denominator: 12. Result: Z_eq = 100/12 ≈ 8.33 Ω. Conjugate impedances in parallel always produce a purely real (resistive) equivalent.
39. C — At series resonance, X_L = X_C, so the inductor and capacitor voltages are equal in magnitude but 180° out of phase, summing to zero. With the reactive voltages cancelling, the source voltage appears entirely across the resistor: V_R = V_source, and the total impedance is purely resistive and minimum.
40. B — Average power: P_avg = (V_p·I_p/2)·cos θ = (100·5/2)·cos 30° = 250·0.866 ≈ 217 W. The factor cos θ accounts for the phase angle between voltage and current. Equivalent expression: P = V_rms·I_rms·cos θ.
41. C — A Norton equivalent network consists of an independent current source I_N in parallel with a Norton resistance R_N. The Thevenin form is its source transformation: V_TH in series with R_TH, where V_TH = I_N·R_N. Both representations produce identical terminal behavior.
42. D — Time constant τ = RC = $1{,}000 \cdot 10^{-5}$ = 10 ms. At t = 5 ms, t/τ = 0.5, so V_C = 5·(1 − e^(−0.5)) = 5·0.3935 ≈ 1.97 V. The capacitor charges to about 39% of its final value after one-half time constant.
43. A — Voltage across an inductor: v(t) = L·di/dt = (50×10^{-3})·d/dt[4·sin(100t)] = 0.05·400·cos(100t) = 20·cos(100t) V. The peak amplitude is 20 V. The voltage leads the current by 90°, characteristic of any pure inductor.
44. B — The transfer function H(s) = (s + 2)/[(s + 1)(s + 3)] has one zero at s = −2 and two poles at s = −1 and s = −3. The numerator degree equals the number of finite zeros and the denominator degree equals the number of poles. Identifying poles and zeros is the first step in any rational-system analysis.
45. D — A causal LTI system is BIBO stable when its impulse response decays to zero, which occurs if and only if all poles of H(s) lie in the open left-half plane (have negative real parts). Zeros do not affect stability; they affect transient shape and the frequency response.
46. B — Initial Value Theorem: $f(0^+)$ = lim_(s→∞) s·F(s). Here $s \cdot F(s) = (3s^2 + 2s)/(s^2 + 4s + 3)$, which tends to 3 as s → ∞. The theorem applies when the limit exists and is valid for the system response immediately after a step input.
47. C — The Fourier transform of a real, even time-domain signal is itself real and even in the frequency domain. This symmetry property follows directly from the FT integral combined with x(t) = x(−t). It is essential when interpreting amplitude spectra of even signals such as cos(ωt).
48. A — For an LTI system, complex exponentials e^(jωt) are eigenfunctions with eigenvalue H(jω). The output is therefore y(t) = H(jω)·e^(jωt), where H(jω) is the system's frequency response evaluated at the input frequency. This property is the foundation of phasor analysis and the Fourier method.
49. D — At t = 4 s, the elapsed time is two time constants (t/τ = 2). The step response reaches 1 − e^(−t/τ) = 1 − e^(−2) ≈ 1 − 0.135 = 0.865. By t = 5τ the response has reached about 99% of its final value, the conventional "fully settled" point.

50. A — In an N-point DFT, frequency samples are spaced uniformly between 0 and f_s, giving bin width Δf = f_s/N. Higher sampling rates or longer transforms produce finer frequency resolution. This relationship is fundamental to spectrum analysis design.
51. B — The impulse response $h[n] = (0.5)^n \cdot u[n]$ is causal because u[n] = 0 for n < 0. It is stable because |0.5| < 1 ensures absolute summability. The system corresponds to a first-order IIR filter with a single pole at z = 0.5.
52. C — A 4-tap moving average is the simplest low-pass FIR filter. Its transfer function $H(z) = (1 + z^{-1} + z^{-2} + z^{-3})/4$ has zeros at the cube roots of unity excluding 1, specifically z = −1, j, and −j. The DC response (z = 1) is preserved at unity gain.
53. D — The frequency response of a digital filter is obtained by evaluating H(z) on the unit circle: substitute z = e^(jω) and compute |H(e^(jω))| for ω ∈ [0, 2π]. This is the discrete-time analog of evaluating H(jω) along the imaginary axis in continuous-time analysis.
54. A — The Nyquist frequency f_s/2 is the maximum frequency that can be represented unambiguously in a sampled signal. Components above this frequency alias into the baseband. The Nyquist-Shannon sampling theorem requires f_s ≥ 2·f_max for perfect reconstruction.
55. D — The convolution sum y[n] = Σ_k x[k]·h[n − k] is the input-output relationship for any discrete-time LTI system, given the impulse response h[n]. This formula expresses every output sample as a linear combination of inputs weighted by h. Convolution in time corresponds to multiplication in the z- and frequency-domains.
56. C — In the hybrid-π BJT small-signal model, r_π represents the input resistance looking into the base-emitter junction and equals β/g_m. Higher transconductance produces lower r_π for the same current gain. This parameter sets the input impedance of common-emitter amplifiers.
57. B — MOSFET saturation drain current: $I\_D = (1/2)\cdot\mu\_n \cdot C\_ox \cdot (W/L) \cdot (V\_GS - V\_T)^2 = (1/2)\cdot(0.5\ \mathrm{mA/V^2})\cdot(3\ \mathrm{V})^2 = 0.25\cdot 9 = 2.25\ \mathrm{mA}$. The square-law dependence on overdrive voltage (V_GS − V_T) is the defining characteristic of MOSFET active-region operation.
58. A — A source-bypass capacitor presents low impedance at signal frequencies, effectively shorting R_S to ground. This eliminates the source-degeneration penalty, restoring the full common-source gain of approximately −g_m·R_D. The bypass capacitor must be sized to be low-impedance at the lowest signal frequency of interest.
59. B — Negative feedback divides the open-loop output impedance by the loop gain factor: R_out,closed ≈ R_out/(1 + Aβ). For typical op-amps with very large open-loop gain, this produces nearly ideal voltage-source behavior at the output. Low output impedance allows the amplifier to drive loads without voltage droop.
60. D — Diode small-signal dynamic resistance: r_d = V_T/I_D = 26 mV/2 mA = 13 Ω at room temperature. The thermal voltage V_T ≈ 25.85 mV at 300 K is rounded to 26 mV in standard references. This dynamic resistance models the AC behavior of the diode around its DC operating point.
61. A — A common-collector (emitter-follower) BJT amplifier has voltage gain slightly less than unity, with the output emitter following the input base. There is no phase inversion. The configuration provides high input impedance, low output impedance, and current gain, making it ideal as a buffer stage.
62. C — Integrator time constant: $\tau = R\cdot C = 10{,}000\cdot 10^{-6} = 10^{-2}\ \mathrm{s} = 10\ \mathrm{ms}$. The output voltage is V_out(t) = −(1/RC)·∫V_in dt, with RC setting the integration scale. Smaller τ produces faster integration response.

63. B — A slew rate of 1 V/μs is the maximum rate at which the op-amp output can change voltage: 1 volt of swing per microsecond. Input signals demanding faster output rates produce slew-rate-limited distortion. Slew rate limits the maximum sinusoidal frequency at full output amplitude.
64. D — In a delta connection, line current relates to phase current by $I\_line = \sqrt{3} \cdot I\_phase$, so $I\_phase = I\_line/\sqrt{3} = 100/1.732 \approx 57.7$ A. Phase voltage equals line voltage in delta, in contrast with the Y connection where voltages differ by $\sqrt{3}$ but currents are equal.
65. A — Under fully balanced load conditions, the three line currents in a Y-connected system sum to zero at the neutral point (vector sum of three equal-magnitude currents 120° apart). No neutral current flows. The neutral conductor exists primarily for unbalanced operation and fault-current paths.
66. C — Eddy currents in a solid magnetic core would flow in loops perpendicular to the flux, dissipating energy as I^2R losses. Laminating the core with thin insulated steel sheets restricts these current paths, dramatically reducing eddy-current losses. Lamination is universal in 50/60 Hz transformer and motor cores.
67. D — A three-phase induction motor draws 5 to 7 times its rated full-load current at start (locked-rotor condition), when slip is unity and the equivalent impedance is at its minimum. This high inrush sizes the upstream protection and starting equipment. Reduced-voltage or VFD starters mitigate this initial current surge.
68. B — A synchronous motor operated with leading power factor draws less reactive power than it supplies, acting as a source of reactive power to the grid — a synchronous condenser. This capability provides power-factor correction for inductive loads on the same bus. Field excitation level controls the leading or lagging behavior.
69. D — Power factor is the cosine of the voltage-current phase angle: $PF = \cos 30° = \sqrt{3}/2 \approx 0.866$. This is a moderately good power factor — typical of partly inductive loads. Loads with PF below 0.85–0.90 typically warrant correction in industrial applications.
70. C — Higher transmission voltage allows the same power $P = V \cdot I$ to be transmitted at proportionally lower current, and I^2R conductor losses scale with the square of current. For a given conductor size, doubling the voltage cuts I^2R losses by approximately a factor of four. This relationship is why long-distance transmission uses 138–765 kV.
71. A — In a DC shunt motor, the speed equation $n = (V - I\_a \cdot R\_a)/(K \cdot \Phi)$ shows that speed varies inversely with flux Φ. Adjusting the field current changes Φ and provides smooth, efficient speed control above base speed. Armature voltage control adjusts speed below base speed.
72. B — In an induction motor's torque-slip curve, slip increases monotonically with load torque up to the breakdown (pull-out) slip. Beyond breakdown slip, torque decreases sharply and the motor stalls. Normal operating slip is small (1–6%) and is set by the load torque demand.
73. B — Lorentz force per unit length: $F/\ell = I \cdot (\hat{y} \times \hat{z}) \cdot B = I \cdot B \cdot \hat{x}$. With $I = 2$ A and $B = 0.5$ T, the magnitude is $2 \cdot 0.5 = 1$ N/m in the +x direction by the right-hand rule ($\hat{y} \times \hat{z} = \hat{x}$). This force is the operating principle of motors and many electromechanical actuators.
74. D — Parallel-plate capacitance: $C = \varepsilon_0 \cdot A/d = (8.85 \times 10^{-12}) \cdot (0.01)/(0.002) = 4.425 \times 10^{-11}$ F = 44.3 pF. Capacitance scales linearly with plate area and inversely with separation. Higher-permittivity dielectrics multiply this baseline value by ε_r.
75. C — The Poynting vector $S = E \times H$ represents the instantaneous power per unit area flowing in the direction of EM wave propagation, measured in W/m². The time-averaged Poynting vector magnitude over a cycle gives the wave intensity. This vector is essential for antenna gain, radar, and free-space optical link analysis.

76. A — Ampère's Law applied to a circular Amperian loop of radius r around a long straight wire gives $B\cdot(2\pi r) = \mu_0\cdot I$, so $B = \mu_0\cdot I/(2\pi r)$. The field forms concentric circles around the wire, with direction set by the right-hand rule. The $1/r$ dependence is the canonical magnetostatics result for an infinite straight conductor.
77. C — Percent overshoot of a second-order step response is $PO = 100\cdot\exp(-\pi\zeta/\sqrt{(1-\zeta^2)})$, a function exclusively of the damping ratio ζ. The natural frequency ω_n affects rise and settling time but not overshoot. This makes ζ the primary tuning parameter for overshoot specification.
78. D — Compare the denominator $s^2 + 10s + 100$ to the canonical form $s^2 + 2\zeta\omega_n\cdot s + \omega_n^2$: $\omega_n^2 = 100$ gives $\omega_n = 10$ rad/s, and $2\zeta\omega_n = 10$ gives $\zeta = 0.5$. This underdamped configuration produces about 16% overshoot in a unit-step response.
79. B — Integral action accumulates persistent error, driving steady-state error to zero for step inputs in a stable closed loop. Too much integral gain can introduce phase lag, slow the closed-loop response, and produce additional overshoot. Tuning K_i balances these competing effects.
80. A — In the state-space realization $\dot{x} = Ax + Bu$, the system poles are precisely the eigenvalues of the matrix A. This follows because the characteristic equation $\det(sI - A) = 0$ sets the natural modes of the system. Pole-placement controllers are designed by choosing K so that $A - BK$ has the desired eigenvalues.
81. A — A system is controllable when there exists an input that drives the state from any initial condition to any final condition in finite time. Mathematically this is captured by the controllability matrix $[B\ AB\ A^2B\ \ldots\ A^{(n-1)}B]$ having full rank. Controllability is a prerequisite for full state-feedback control.
82. C — A lead compensator with $a < b$ contributes positive phase shift (lead) over a band of frequencies between the zero and pole. This added phase improves the system's phase margin and accelerates the transient response. Lead compensators are the frequency-domain analog of derivative action in PID controllers.
83. D — Construct the Routh array for $s^3 + 4s^2 + 5s + K$: row $s^3 = [1, 5]$, row $s^2 = [4, K]$, row $s^1 = [(4\cdot5 - 1\cdot K)/4, 0] = [(20 - K)/4, 0]$, row $s^0 = [K]$. All first-column entries must be positive: $(20 - K)/4 > 0$ requires $K < 20$, and $K > 0$. Stability requires $0 < K < 20$.
84. B — Carson's rule for FM bandwidth: $BW \approx 2(\beta + 1)\cdot f_m = 2\cdot(5 + 1)\cdot 1$ kHz $= 12$ kHz. The formula captures about 98% of the signal power and is the standard wideband-FM bandwidth estimate. Commercial FM broadcasting uses $\beta \approx 5$ with $f_m = 15$ kHz, yielding 180 kHz bandwidth.
85. C — E_b/N_0 normalizes signal-to-noise ratio per bit and per unit of noise spectral density, making it the standard modulation-independent performance metric. BER curves are universally plotted versus E_b/N_0 in dB to compare schemes such as BPSK, QPSK, and QAM on equal footing. Shannon's bound is also expressed in these terms.
86. A — Noise power in dBm at room temperature: $10\cdot\log_{10}(k\cdot T\cdot B/1\text{ mW}) = -174 + 10\cdot\log_{10}(B)$. For $B = 1$ MHz: $-174 + 60 = -114$ dBm. The -174 dBm/Hz noise floor at 290 K is a widely used reference value in RF receiver design.
87. B — Frequency-Division Multiplexing assigns each input signal a distinct portion of the channel's frequency spectrum, separated by guard bands. The combined signal is then transmitted simultaneously over a single physical channel. FDM dominated analog telephony and broadcasting before digital time-division and packet-based methods became prevalent.
88. D — OFDM subcarriers are mutually orthogonal when the subcarrier spacing equals the reciprocal of the OFDM symbol duration, $\Delta f = 1/T_s$. This condition ensures that each subcarrier's spectral peaks coincide with the nulls of neighboring subcarriers, eliminating inter-carrier interference. OFDM underpins LTE, Wi-Fi, and DVB-T standards.

89. C — The Domain Name System translates human-readable hostnames (such as www.example.com) into the numeric IP addresses required for routing. DNS uses a hierarchical, distributed database of name servers. Without DNS, users would need to memorize numeric addresses for every Internet service they access.
90. B — Applying a /26 mask to a /24 network borrows 2 bits from the host portion, producing $2^2 = 4$ subnets. Each subnet has 6 host bits = 64 addresses, minus the network and broadcast addresses, giving 62 usable hosts per subnet. This subdivision pattern is common in office network design.
91. D — HTTP operates at OSI Layer 7 (Application), defining client-server interactions for web resources. It relies on lower layers — TCP at Layer 4 for reliable delivery, IP at Layer 3 for routing — but provides the application-level protocol semantics used by browsers and web services. Modern variants include HTTPS, HTTP/2, and HTTP/3.
92. A — Ethernet switches operate at Layer 2 and forward frames based on the destination MAC address contained in the frame header. The switch maintains a MAC-address table mapping each address to a port, learned by observing source addresses on incoming frames. Unknown destinations cause flooding to all ports except the source.
93. C — Convert 47 to binary by summing powers of 2: $47 = 32 + 8 + 4 + 2 + 1 = 2^5 + 2^3 + 2^2 + 2^1 + 2^0 = 101111_2$. Verification by positional sum: $1·32 + 0·16 + 1·8 + 1·4 + 1·2 + 1·1 = 47$. Binary conversion is a fundamental digital-systems skill.
94. B — Apply the distributive and complement laws: $(A + B)·(A + B') = A·A + A·B' + A·B + B·B' = A + A·(B + B') + 0 = A + A = A$. Equivalently, this is an instance of the consensus form $(X + Y)·(X + Y') = X$. The identity is one of the absorption-style Boolean simplifications.
95. A — In a synchronous sequential circuit, every flip-flop is driven by a common clock signal, and state transitions occur only on the active clock edge (rising or falling depending on the device). Between clock edges, the state is stable. Synchronous design simplifies timing analysis dramatically compared to asynchronous designs.
96. D — An unsigned n-bit register represents values 0 to $2^n - 1$. For $n = 16$: range is 0 to $2^{16} - 1 = 65{,}535$. Signed two's complement representation would give the symmetric range −32,768 to +32,767 instead. Choice of signed versus unsigned depends on whether negative values must be represented.
97. C — K-map minterms are at (A = 0, B = 0), (A = 0, B = 1), and (A = 1, B = 1). Grouping the two cells along the A = 0 row covers A′. Grouping the two cells in the B = 1 column covers B. The minimum sum-of-products expression is $A' + B$.
98. A — A T-type flip-flop with T = 1 at the active clock edge toggles the output: Q transitions from 0 to 1 or from 1 to 0. With T = 0 the output is held unchanged. T flip-flops are commonly cascaded to form binary counters.
99. B — A NAND gate computes NOT-AND, producing LOW output only when every input is HIGH (because AND of all HIGH inputs is HIGH, and NOT of HIGH is LOW). For any LOW input, the AND output is LOW and the NAND output is HIGH. NAND is one of the two universal gates, along with NOR.
100. D — In a CMOS NAND gate, the pull-up network connecting V_DD to the output consists of PMOS transistors in parallel. The pull-down network to ground uses NMOS transistors in series. This dual-network arrangement realizes the function NOT(A·B), matching the NAND truth table.
101. C — In a ripple counter, each flip-flop stage triggers the next, so the carry propagates serially through the chain. The total propagation delay before the count output is valid equals approximately N·t_FF for an N-stage counter. Synchronous counters clock all flip-flops simultaneously to eliminate this cumulative ripple delay.

102. B — The CPU instruction cycle consists of three sequential phases: fetch (read the instruction from memory), decode (interpret the opcode), execute (perform the operation). In a pipelined CPU, multiple instructions are in different phases simultaneously, but each individual instruction still follows the same sequence. This cycle is the fundamental abstraction of CPU operation.

103. A — Cache effectiveness depends on programs revisiting recently accessed addresses (temporal locality) and accessing nearby addresses sequentially (spatial locality). Random access patterns defeat caching. Programmers can dramatically improve performance by structuring code and data layouts to exploit locality.

104. C — A hypervisor (Type 1 bare-metal or Type 2 hosted) mediates virtual machine access to physical resources (CPU, memory, I/O) and enforces isolation between guests. This abstraction allows multiple operating systems to share hardware safely on the same physical host. Hypervisors are the foundation of modern cloud computing infrastructure.

105. D — MIPS (Million Instructions Per Second) ignores differences in instruction complexity across instruction sets — a single CISC instruction may do the work of many RISC instructions. Comparing CPUs with different ISAs by MIPS alone can therefore be highly misleading. Benchmark suites such as SPEC provide more meaningful cross-architecture comparisons.

106. B — A 32-bit virtual address can represent $2^{32} \approx 4.29$ billion distinct byte locations, or roughly 4 GB of addressable memory per process. This was the standard process address space limit on 32-bit operating systems. Modern 64-bit systems extend this to a vastly larger 2^{64} address space.

107. A — The daily stand-up is a short (typically 15-minute) meeting in which each team member briefly reports what they completed yesterday, what they plan for today, and any blockers they face. The stand-up format encourages brevity and surfaces issues quickly. It is one of the most distinctive practices of Scrum and other Agile methodologies.

108. B — CI/CD stands for Continuous Integration and Continuous Delivery (or Continuous Deployment). CI automates code integration and testing on every commit, while CD automates the release or deployment process to production-like environments. Together they form the backbone of modern DevOps workflows.

109. C — The principle "favor composition over inheritance" recommends building object behavior by assembling smaller objects (has-a relationships) rather than rigid class hierarchies (is-a relationships). Composition produces more flexible, less tightly coupled designs that are easier to modify and extend. Deep inheritance hierarchies often become fragile and resist change.

110. D — A Git commit captures a snapshot of all tracked files at a specific point in time, along with metadata (author, timestamp, message) and a pointer to the previous commit. The chain of commits forms the complete version history of the project. Other Git operations such as push, merge, and clone operate on or move commits between repositories.