GATE Electronics and Communication Engineering

Sample Paper – 9

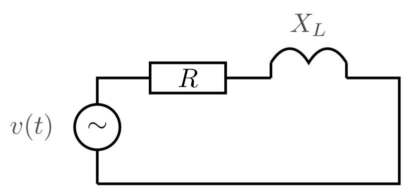
Duration: 128 Minutes | **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Electronics and Communication Engineering** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Unless stated otherwise take $n_i = 1.5 \times 10^{10}$ cm^{-3} for silicon, thermal voltage $V_T = 25$ mV at room temperature, $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m, $\mu_0 = 4\pi \times 10^{-7}$ H/m and $c = 3 \times 10^8$ m/s.

Networks and Circuit Analysis

Q1. In the sinusoidal steady state, the series circuit shown carries a resistance $R = 3\ \Omega$ in series with an inductive reactance $X_L = 4\ \Omega$. The magnitude of the total impedance $|Z| = \sqrt{R^2 + X_L^2}$ seen by the source is: **[1 mark]**



(A) $7\ \Omega$

(B) $5\ \Omega$

(C) $1\ \Omega$

(D) $25\ \Omega$

Q2. An ideal capacitor of $C = 100\ \mu$F is driven in the sinusoidal steady state by a source of angular frequency $\omega = 100$ rad/s. The magnitude of the capacitive reactance $X_C = \dfrac{1}{\omega C}$ is: **[1 mark]**

(A) $100\ \Omega$

(B) $10\ \Omega$

(C) $1000\ \Omega$

(D) $0.01\ \Omega$

Q3. A series combination of a resistance $R = 10\ \Omega$ and an inductive reactance $X_L = 10\ \Omega$ is excited by a sinusoidal source. The phase angle of the total impedance, $\theta = \tan^{-1}\left(\frac{X_L}{R}\right)$, is: **[1 mark]**

(A) 0°

(B) 90°

(C) 30°

(D) 45°

Q4. A sinusoidal voltage of peak amplitude $V_m = 10$ V appears across a resistor $R = 100\ \Omega$. The average (real) power dissipated, $P = \dfrac{V_m^2}{2R}$, is: **[1 mark]**

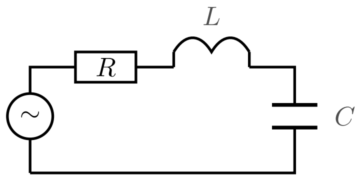
(A) 1 W

(B) 2 W

(C) 0.25 W

(D) 0.5 W

Q5. The series RLC circuit shown is driven at its resonant frequency, with $R = 20\ \Omega$. At resonance the inductive and capacitive reactances cancel, so the total impedance seen by the source is: **[1 mark]**



(A) $20\ \Omega$

(B) $0\ \Omega$

(C) infinite

(D) $40\ \Omega$

Q6. A sinusoidal current in a branch is $i(t) = 4\cos(\omega t)$ A. Its root-mean-square (RMS) value, $I_{rms} = \dfrac{I_m}{\sqrt{2}}$, is nearest to: **[1 mark]**

(A) 4 A

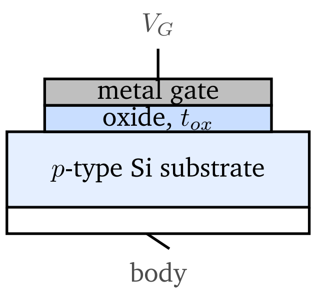
(B) 2 A

(C) 8 A

(D) 2.83 A

Electronic Devices

Q7. The MOS capacitor shown has a silicon-dioxide gate insulator of relative permittivity $\varepsilon_{ox} = 3.9$ and thickness $t_{ox} = 10$ nm. The oxide capacitance per unit area, $C_{ox} = \dfrac{\varepsilon_{ox}\varepsilon_0}{t_{ox}}$, is nearest to: **[1 mark]**



(A) 3.45×10^{-4} F/m^2

(B) 3.45×10^{-3} F/m^2

(C) 3.45×10^{-2} F/m^2

(D) 3.45×10^{-8} F/m^2

Q8. An n-channel MOSFET has a zero-bias threshold voltage $V_{t0} = 0.5$ V, body-effect coefficient $\gamma = 0.4\ \sqrt{\text{V}}$ and surface potential term $2\phi_F = 0.6$ V. When a source-to-body reverse bias of $V_{SB} = 1$ V is applied, the threshold voltage $V_t = V_{t0} + \gamma\left(\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F}\right)$ is nearest to: **[1 mark]**

(A) 0.70 V

(B) 0.50 V

(C) 0.90 V

(D) 0.60 V

Q9. A silicon pn junction is doped with $N_a = N_d = 10^{16}$ cm^{-3} on the two sides. Taking $n_i = 1.5 \times 10^{10}$ cm^{-3} and $V_T = 25$ mV, the built-in (contact) potential $V_{bi} = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right)$ is nearest to: **[1 mark]**

(A) 0.67 V

(B) 0.34 V

(C) 1.34 V

(D) 0.12 V

Q10. In a uniformly doped silicon bar an electric field $E = 1000$ V/cm is applied. The electrons have mobility $\mu_n = 1000$ cm^2/V·s. The electron drift velocity $v_d = \mu_n E$ is: **[1 mark]**

(A) 1×10^3 cm/s

(B) 1×10^9 cm/s

(C) 1×10^4 cm/s

(D) 1×10^6 cm/s

Q11. For electrons in silicon the mobility is $\mu_n = 1000\ \text{cm}^2/\text{V}\cdot\text{s}$. Using the Einstein relation $\dfrac{D_n}{\mu_n} = V_T$ with $V_T = 25$ mV, the electron diffusion coefficient D_n is: **[1 mark]**

(A) $40\ \text{cm}^2/\text{s}$

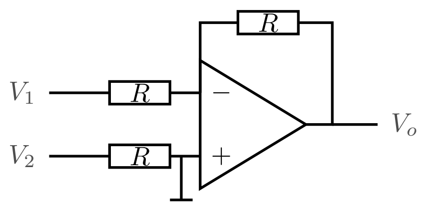
(B) $1000\ \text{cm}^2/\text{s}$

(C) $25\ \text{cm}^2/\text{s}$

(D) $0.025\ \text{cm}^2/\text{s}$

Analog Circuits

Q12. The ideal-op-amp difference amplifier shown uses four equal resistors of value R. Its output is $V_o = \dfrac{R}{R}(V_2 - V_1) = V_2 - V_1$. For $V_1 = 1$ V and $V_2 = 3$ V, the output voltage is: **[1 mark]**



(A) 4 V

(B) -2 V

(C) 2 V

(D) 0 V

Q13. A three-op-amp instrumentation amplifier has two equal input-stage feedback resistors $R_1 = 50\ \text{k}\Omega$ and a gain-setting resistor $R_g = 10\ \text{k}\Omega$; the output difference stage has unity gain. The overall differential gain $A = 1 + \dfrac{2R_1}{R_g}$ is: **[1 mark]**

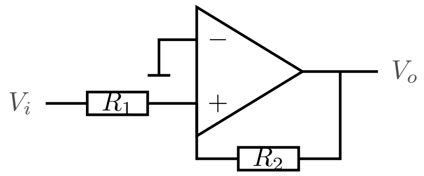
(A) 11

(B) 10

(C) 5

(D) 21

Q14. The non-inverting Schmitt-trigger comparator shown uses $R_1 = 10$ kΩ (input) and $R_2 = 20$ kΩ (feedback), with output saturation levels $\pm V_{sat} = \pm 12$ V. Its two trip points are $\pm \frac{R_1}{R_2} V_{sat}$, so the hysteresis width $V_H = 2\frac{R_1}{R_2} V_{sat}$ is: **[1 mark]**



(A) 6 V

(B) 3 V

(C) 24 V

(D) 12 V

Q15. A difference amplifier has a differential-mode gain $A_d = 100$ and a common-mode gain $A_{cm} = 0.01$. Its common-mode rejection ratio in decibels, $\text{CMRR}_{dB} = 20\log_{10}\left(\frac{A_d}{A_{cm}}\right)$, is: **[1 mark]**

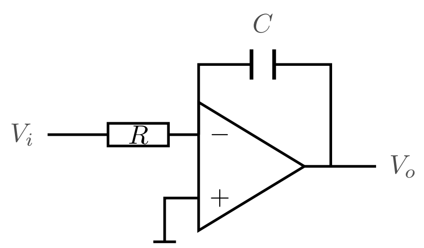
(A) 40 dB

(B) 100 dB

(C) 20 dB

(D) 80 dB

Q16. The ideal-op-amp integrator shown has $R = 1$ MΩ and $C = 1$ μF, and starts from zero output. For a constant input $V_i = 1$ V the output is $V_o(t) = -\frac{1}{RC}\int_0^t V_i\,dt$. Its value at $t = 2$ s is: **[1 mark]**



(A) -1 V

(B) 2 V

(C) -2 V

(D) -4 V

Q17. A first-order active low-pass filter built around an op-amp has $R = 1.6$ kΩ and $C = 0.1$ μF setting its corner. The -3 dB cut-off frequency $f_c = \frac{1}{2\pi RC}$ is nearest to: **[1 mark]**

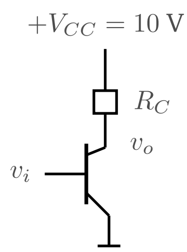
(A) 100 Hz

(B) 1 kHz

(C) 10 kHz

(D) 159 Hz

Q18. The common-emitter BJT stage shown is biased at $V_{CC} = 10$ V with a collector resistor $R_C = 2$ kΩ and a quiescent collector current $I_C = 2$ mA. The quiescent collector-emitter voltage $V_{CE} = V_{CC} - I_C R_C$ is: **[1 mark]**



(A) 4 V

(B) 6 V

(C) 10 V

(D) 2 V

Digital Circuits

Q19. Using the rules of Boolean algebra, the expression $Y = AB + A\bar{B}$ simplifies to: **[1 mark]**

(A) A

(B) B

(C) AB

(D) $A + B$

Q20. The hexadecimal number $(2F)_{16}$ has the decimal (base-10) value: **[1 mark]**

(A) 31

(B) 47

(C) 45

(D) 63

Q21. The four-variable function $F(A, B, C, D) = \sum m(0, 2, 8, 10)$ is plotted on the Karnaugh map shown (rows AB, columns CD). The four ones sit at the corners of the map. The minimal sum-of-products expression for F is: **[2 marks]**

$AB\backslash CD$	00	01	11	10
00	1	0	0	1
01	0	0	0	0
11	0	0	0	0
10	1	0	0	1

(A) $\bar{B}\,\bar{D}$

(B) $\bar{B}D$

(C) $B\bar{D}$

(D) $\bar{A}\,\bar{C}$

Q22. A standard TTL gate can sink a maximum output-low current of $I_{OL} = 16$ mA, while each driven input draws an input-low current of $I_{IL} = 1.6$ mA. The maximum fan-out (number of like gates the output can drive) is: **[2 marks]**

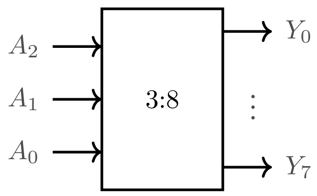
(A) 5

(B) 10

(C) 20

(D) 8

Q23. The 3-to-8 line decoder shown accepts a 3-bit address and asserts its outputs one at a time. For any single valid input combination, the number of output lines that are active (asserted) is: **[2 marks]**



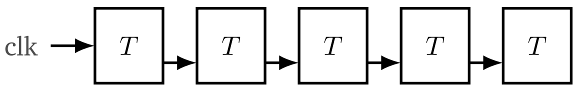
(A) 8

(B) 1

(C) 3

(D) 0

Q24. The asynchronous ripple counter shown is built from five negative-edge-triggered T flip-flops (each with $T = 1$). The number of distinct states through which the counter cycles is 2^n. The count is: **[2 marks]**



five negative-edge T flip-flops

(A) 32

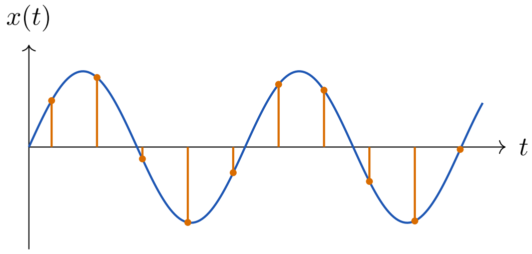
(B) 31

(C) 16

(D) 5

Signals and Systems

Q25. A pure sinusoid of frequency 7 kHz is sampled at $f_s = 10$ kHz, as sketched (dots are the samples). Because 7 kHz exceeds the Nyquist limit of 5 kHz, the reconstructed tone appears at the alias frequency $|f - f_s|$, which is: **[2 marks]**



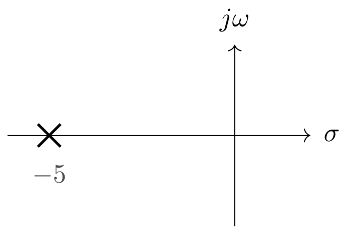
(A) 7 kHz

(B) 10 kHz

(C) 3 kHz

(D) 5 kHz

Q26. A causal LTI system has the transfer function $H(s) = \dfrac{5}{s+5}$, whose single pole is marked ($\times$) in the plot. Its d.c. gain $H(0)$ is: **[2 marks]**



(A) 5

(B) 1

(C) 0.2

(D) 0

Q27. A discrete-time signal is $x[n] = (0.25)^n u[n]$. The sum of all its samples, $\displaystyle\sum_{n=-\infty}^{\infty} x[n]$, is: **[2 marks]**

(A) 0.25

(B) 4

(C) 0.75

(D) 1.333

Q28. A signal is $x(t) = 2 + 3\cos(\omega_0 t)$ volts, taken across a $1\ \Omega$ resistor. Its average power (d.c. power plus a.c. power) is $P = V_{dc}^2 + \frac{V_m^2}{2}$, which equals: **[2 marks]**

(A) 13 W

(B) 4 W

(C) 4.5 W

(D) 8.5 W

Q29. Two finite-length discrete sequences of lengths 5 and 4 samples respectively are linearly convolved. The length (number of samples) of the resulting sequence, $N_1 + N_2 - 1$, is: **[2 marks]**

(A) 9

(B) 5

(C) 8

(D) 4

Q30. A continuous-time signal that contains a 5 kHz component is sampled at $f_s = 8$ kHz. Because 5 kHz lies above the folding frequency of 4 kHz, this component appears (aliases) at the frequency $|f - f_s|$, which is: **[2 marks]**

(A) 3 kHz

(B) 5 kHz

(C) 8 kHz

(D) 13 kHz

Control Systems

Q31. A standard second-order system has the characteristic equation $s^2 + 2s + 100 = 0$. Comparing with $s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$, the damping ratio ζ of the system is: **[2 marks]**

(A) 1

(B) 0.5

(C) 0.2

(D) 0.1

Q32. The characteristic equation of a feedback system is $s^3 + s^2 + 2s + 8 = 0$. Using the Routh–Hurwitz criterion, the number of closed-loop poles lying in the right half of the s-plane is: **[2 marks]**

(A) 0

(B) 3

(C) 2

(D) 1

Q33. A unity-feedback system has open-loop transfer function $G(s) = \dfrac{20}{s(s+5)}$. For a unit-ramp input the steady-state error is $e_{ss} = \dfrac{1}{K_v}$ with $K_v = \lim_{s\to 0} s\,G(s)$. The value of e_{ss} is: **[2 marks]**

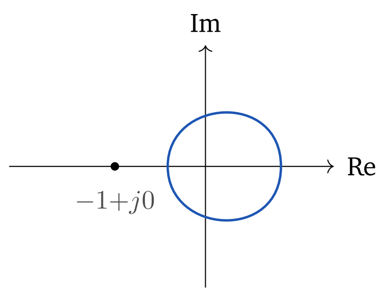
(A) 0

(B) infinite

(C) 0.5

(D) 0.25

Q34. Consider a unity-feedback loop whose open-loop transfer function $G(s)H(s)$ has no poles in the right half of the s-plane ($P = 0$). By the Nyquist stability criterion, the closed-loop system is stable if and only if the Nyquist plot of $G(j\omega)H(j\omega)$ encircles the critical point $-1 + j0$: **[2 marks]**



(A) zero times (no encirclement)

(B) once clockwise

(C) twice clockwise

(D) once counter-clockwise

Q35. A standard second-order system has undamped natural frequency $\omega_n = 10$ rad/s and damping ratio $\zeta = 0.6$. Its damped natural frequency $\omega_d = \omega_n\sqrt{1-\zeta^2}$ is: **[2 marks]**

(A) 10 rad/s

(B) 8 rad/s

(C) 6 rad/s

(D) 4 rad/s

Communications

Q36. A two-stage receiver front end has a first stage of noise factor $F_1 = 2$ and available power gain $G_1 = 10$, followed by a second stage of noise factor $F_2 = 6$. By Friis' formula the overall noise factor $F = F_1 + \dfrac{F_2 - 1}{G_1}$ is: **[2 marks]**

(A) 8

(B) 2.5

(C) 6

(D) 2

Q37. A resistor is at temperature $T = 290$ K and feeds a receiver of noise-equivalent bandwidth $B = 1$ MHz. The available thermal noise power $N = kTB$ (with $k = 1.38 \times 10^{-23}$ J/K) is nearest to: **[2 marks]**

(A) 1.38×10^{-23} W

(B) 4×10^{-21} W

(C) 4×10^{-9} W

(D) 4×10^{-15} W

Q38. At the detector of a receiver the signal-to-noise power ratio is SNR $=$ 1000. Expressed in decibels, $\text{SNR}_{dB} = 10\log_{10}(\text{SNR})$, this equals: **[2 marks]**

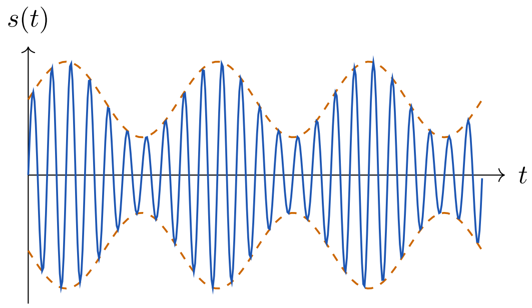
(A) 10 dB

(B) 20 dB

(C) 30 dB

(D) 1000 dB

Q39. A carrier is amplitude-modulated to a modulation index $\mu = 0.5$, giving the envelope shown. The fraction of the total transmitted power carried by the two sidebands, $\dfrac{\mu^2/2}{1+\mu^2/2}$, is nearest to: **[2 marks]**



(A) 25%

(B) 11.1%

(C) 50%

(D) 33%

Q40. A discrete memoryless source emits three symbols with probabilities $\{0.5,\ 0.25,\ 0.2$
The source entropy $H = -\sum p_i \log_2 p_i$ is: **[2 marks]**

(A) 2 bits/symbol

(B) 3 bits/symbol

(C) 1.5 bits/symbol

(D) 1 bit/symbol

Q41. A commercial FM signal has a peak frequency deviation $\Delta f = 75$ kHz for a modulating tone of frequency $f_m = 15$ kHz. By Carson's rule the transmission bandwidth $B = 2(\Delta f + f_m)$ is: **[2 marks]**

(A) 180 kHz

(B) 150 kHz

(C) 75 kHz

(D) 90 kHz

Electromagnetics

Q42. A uniform plane wave travels in a lossless non-magnetic dielectric of relative permittivity $\varepsilon_r = 4$. Its phase velocity $u_p = \dfrac{c}{\sqrt{\varepsilon_r}}$ (with $c = 3 \times 10^8$ m/s) is: **[2 marks]**

(A) 3×10^8 m/s

(B) 1.5×10^8 m/s

(C) 0.75×10^8 m/s

(D) 6×10^8 m/s

Q43. A uniform plane wave has two equal-amplitude, mutually orthogonal electric-field components (E_x and E_y) that are in time-phase quadrature, i.e. a 90° phase difference. The polarization of this wave is: **[2 marks]**

(A) linear

(B) elliptical

(C) circular

(D) unpolarized

Q44. A uniform plane wave propagates in the lossless non-magnetic dielectric of $\varepsilon_r = 4$. The intrinsic (wave) impedance of the medium, $\eta = \dfrac{\eta_0}{\sqrt{\varepsilon_r}}$ with $\eta_0 = 377\ \Omega$, is nearest to: **[2 marks]**

(A) $188.5\ \Omega$

(B) $377\ \Omega$

(C) $754\ \Omega$

(D) $94\ \Omega$

Q45. A uniform plane wave of frequency 300 MHz (free-space wavelength $\lambda_0 = 1$ m) enters the lossless non-magnetic dielectric of $\varepsilon_r = 4$. Its wavelength in the medium, $\lambda = \dfrac{\lambda_0}{\sqrt{\varepsilon_r}}$, is: **[2 marks]**

(A) 1 m

(B) 2 m

(C) 0.5 m

(D) 0.25 m

Q46. A uniform plane wave in free space has an electric-field amplitude $E_0 = 377$ V/m. Its time-average Poynting power density, $S_{avg} = \dfrac{E_0^2}{2\eta_0}$ with $\eta_0 = 377\ \Omega$, is: **[2 marks]**

(A) 377 W/m^2

(B) 188.5 W/m^2

(C) 94.25 W/m^2

(D) 754 W/m^2

Detailed Solutions

Q1.

Solution

Concept – magnitude of a series R–L impedance: In the sinusoidal steady state a resistance and an inductive reactance in series add as perpendicular phasors, so the magnitude is $|Z| = \sqrt{R^2 + X_L^2}$.

Step 1 – list the data: $R = 3\ \Omega$, $X_L = 4\ \Omega$.

Step 2 – square the resistance: $R^2 = 3^2 = 9$

Step 3 – square the reactance: $X_L^2 = 4^2 = 16$

Step 4 – add the two squares: $R^2 + X_L^2 = 9 + 16 = 25$

Step 5 – take the square root: $|Z| = \sqrt{25} = 5\ \Omega$

Final Answer: $|Z| = 5\ \Omega \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – capacitive reactance: The reactance of a capacitor is $X_C = \dfrac{1}{\omega C}$.

Step 1 – convert the capacitance to base units: $C = 100\ \mu\text{F} = 100 \times 10^{-6}\ \text{F} = 1 \times 10^{-4}\ \text{F}$

Step 2 – form the product ωC: $\omega C = 100 \times (1 \times 10^{-4})$

$\omega C = 1 \times 10^{-2}$

Step 3 – take the reciprocal: $X_C = \dfrac{1}{1 \times 10^{-2}}$

$X_C = 100\ \Omega$

Final Answer: $X_C = 100\ \Omega \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept – phase angle of a series impedance: For $Z = R + jX_L$ the phase angle is $\theta = \tan^{-1}\left(\frac{X_L}{R}\right)$.

Step 1 – list the data: $R = 10\ \Omega$, $X_L = 10\ \Omega$.

Step 2 – form the ratio of reactance to resistance: $\dfrac{X_L}{R} = \dfrac{10}{10} = 1$

Step 3 – take the inverse tangent: $\theta = \tan^{-1}(1)$

Step 4 – evaluate: $\theta = 45^\circ$

Final Answer: $\theta = 45^\circ \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – average power in a resistor from a sinusoid: For a sinusoidal voltage of peak value V_m across a resistor R, the average power is $P = \dfrac{V_m^2}{2R}$ (the factor 2 comes from the RMS-to-peak relation).

Step 1 – list the data: $V_m = 10$ V, $R = 100\ \Omega$.

Step 2 – square the peak voltage: $V_m^2 = 10^2 = 100$

Step 3 – form the denominator: $2R = 2 \times 100 = 200$

Step 4 – divide: $P = \dfrac{100}{200}$

$P = 0.5$ W

Final Answer: $P = 0.5$ W $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept – impedance of a series RLC circuit at resonance: At the resonant frequency the inductive reactance and capacitive reactance are equal in magnitude and opposite in sign, so they cancel and the net reactance is zero.

Step 1 – write the impedance in general: $Z = R + j\,(X_L - X_C)$

Step 2 – apply the resonance condition: At resonance $X_L = X_C$, hence $X_L - X_C = 0$.

Step 3 – substitute: $Z = R + j\,(0) = R$

Step 4 – insert the resistance value: $Z = 20\ \Omega$

Why the other options are wrong:

- B, $0\ \Omega$: would need $R = 0$; the resistor is still present at resonance.

- C, infinite: is the parallel (anti-resonance) case, not a series circuit.
- D, 40 Ω: double-counts a reactive term that has actually cancelled.

Final Answer: $Z = 20\ \Omega \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – RMS value of a sinusoid: For a sinusoid of peak (amplitude) value I_m, the RMS value is $I_{rms} = \dfrac{I_m}{\sqrt{2}}$.

Step 1 – read the peak value: The current is $i(t) = 4\cos(\omega t)$, so $I_m = 4$ A.

Step 2 – divide by $\sqrt{2}$: $I_{rms} = \dfrac{4}{\sqrt{2}}$

Step 3 – rationalise: $I_{rms} = \dfrac{4}{1.4142} = 2\sqrt{2}$

Step 4 – evaluate: $I_{rms} = 2.83$ A

Final Answer: $I_{rms} = 2.83\text{ A} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – oxide capacitance per unit area of a MOS capacitor: The gate oxide behaves as a parallel-plate capacitor, so $C_{ox} = \dfrac{\varepsilon_{ox}\varepsilon_0}{t_{ox}}$.

Step 1 – form the oxide permittivity: $\varepsilon_{ox}\varepsilon_0 = 3.9 \times (8.854 \times 10^{-12})$

$\varepsilon_{ox}\varepsilon_0 = 3.453 \times 10^{-11}$ F/m

Step 2 – convert the oxide thickness: $t_{ox} = 10\text{ nm} = 10 \times 10^{-9}\text{ m} = 1 \times 10^{-8}\text{ m}$

Step 3 – divide: $C_{ox} = \dfrac{3.453 \times 10^{-11}}{1 \times 10^{-8}}$

Step 4 – combine the powers of ten: $C_{ox} = 3.453 \times 10^{-3}\text{ F/m}^2$

Step 5 – round: $C_{ox} \approx 3.45 \times 10^{-3}\text{ F/m}^2$

Final Answer: $C_{ox} \approx 3.45 \times 10^{-3}\text{ F/m}^2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept – body (substrate) effect on threshold voltage: Applying a source-to-body reverse bias raises the threshold according to $V_t = V_{t0} + \gamma\left(\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F}\right)$.

Step 1 – evaluate the first square root: $\sqrt{2\phi_F + V_{SB}} = \sqrt{0.6+1} = \sqrt{1.6} = 1.2649$

Step 2 – evaluate the second square root: $\sqrt{2\phi_F} = \sqrt{0.6} = 0.7746$

Step 3 – take the difference: $1.2649 - 0.7746 = 0.4903$

Step 4 – multiply by the body-effect coefficient: $\gamma \times 0.4903 = 0.4 \times 0.4903 = 0.1961$

Step 5 – add the zero-bias threshold: $V_t = 0.5 + 0.1961 = 0.6961$

Step 6 – round: $V_t \approx 0.70$ V

Final Answer: $V_t \approx 0.70 \text{ V} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – built-in potential of a pn junction: $V_{bi} = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right)$.

Step 1 – form the product of the two dopings: $N_a N_d = (10^{16}) \times (10^{16}) = 10^{32}$ cm^{-6}

Step 2 – square the intrinsic concentration: $n_i^2 = (1.5\times10^{10})^2 = 2.25\times10^{20}$ cm^{-6}

Step 3 – form the ratio inside the logarithm: $\frac{N_a N_d}{n_i^2} = \frac{10^{32}}{2.25 \times 10^{20}} = 4.44 \times 10^{11}$

Step 4 – take the natural logarithm: $\ln(4.44 \times 10^{11}) = 26.82$

Step 5 – multiply by the thermal voltage: $V_{bi} = 0.025 \times 26.82$

$V_{bi} = 0.6705$ V

Step 6 – round: $V_{bi} \approx 0.67$ V

Final Answer: $V_{bi} \approx 0.67 \text{ V} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q9

Q10.

Solution

Concept – drift velocity in an electric field: In the low-field (ohmic) regime the drift velocity is proportional to the field, $v_d = \mu_n E$.

Step 1 – list the data: $\mu_n = 1000\ \text{cm}^2/\text{V}\cdot\text{s}$, $E = 1000$ V/cm.

Step 2 – substitute into the formula: $v_d = 1000 \times 1000$

Step 3 – multiply: $v_d = 1 \times 10^6$ cm/s

Why the other options are wrong:

- A, 10^3 cm/s and C, 10^4 cm/s: drop one or two factors of ten from the multiplication.
- B, 10^9 cm/s: exceeds the saturation velocity of carriers in silicon ($\sim 10^7$ cm/s) and is unphysical here.

Final Answer: $v_d = 1 \times 10^6$ cm/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept – Einstein relation between diffusion and mobility: $\dfrac{D_n}{\mu_n} = V_T$, hence $D_n = \mu_n V_T$.

Step 1 – list the data: $\mu_n = 1000\ \text{cm}^2/\text{V}\cdot\text{s}$, $V_T = 25$ mV $= 0.025$ V.

Step 2 – multiply the mobility by the thermal voltage: $D_n = 1000 \times 0.025$

Step 3 – evaluate: $D_n = 25\ \text{cm}^2/\text{s}$

Final Answer: $D_n = 25\ \text{cm}^2/\text{s} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q11

Q12.

Solution

Concept – difference amplifier with equal resistors: When all four resistors of an op-amp difference amplifier are equal, the output is $V_o = V_2 - V_1$ (unity differential gain, applied to the non-inverting and inverting inputs).

Step 1 – list the input voltages: $V_1 = 1$ V (inverting side), $V_2 = 3$ V (non-inverting side).

Step 2 – form the difference: $V_o = V_2 - V_1 = 3 - 1$

Step 3 – evaluate: $V_o = 2$ V

Why the other options are wrong:

- A, 4 V: adds the inputs instead of subtracting them.
- B, -2 V: reverses the sign, i.e. computes $V_1 - V_2$.
- D, 0 V: would require $V_1 = V_2$.

Final Answer: $V_o = 2\text{ V} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – gain of a three-op-amp instrumentation amplifier: With the output difference stage set to unity gain, the overall differential gain is fixed by the input stage: $A = 1 + \dfrac{2R_1}{R_g}$.

Step 1 – form the resistor ratio: $\dfrac{2R_1}{R_g} = \dfrac{2 \times 50\text{ k}\Omega}{10\text{ k}\Omega}$

Step 2 – simplify the numerator: $2 \times 50\text{ k}\Omega = 100\text{ k}\Omega$

Step 3 – divide: $\dfrac{100\text{ k}\Omega}{10\text{ k}\Omega} = 10$

Step 4 – add one: $A = 1 + 10 = 11$

Why the other options are wrong:

- B, 10: forgets the "$+1$" term.
- C, 5: uses R_1/R_g without the factor of 2.
- D, 21: doubles the ratio a second time.

Final Answer: $A = 11 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – hysteresis of a non-inverting Schmitt trigger: The two switching thresholds sit symmetrically at $\pm\frac{R_1}{R_2}V_{sat}$, so the hysteresis (total width between them) is $V_H = 2\,\frac{R_1}{R_2}V_{sat}$.

Step 1 – form the resistor ratio: $\frac{R_1}{R_2} = \frac{10\text{ k}\Omega}{20\text{ k}\Omega} = 0.5$

Step 2 – multiply by the saturation level: $\frac{R_1}{R_2}V_{sat} = 0.5 \times 12 = 6\text{ V}$

Step 3 – this is one trip point; find both: Upper trip point $= +6$ V, lower trip point $= -6$ V.

Step 4 – take the difference (hysteresis width): $V_H = 6 - (-6) = 12\text{ V}$

Why the other options are wrong:

- A, 6 V: is only one trip point, not the full width.
- B, 3 V: halves the ratio once too often.
- C, 24 V: doubles the full swing $2V_{sat}$ by mistake.

Final Answer: $V_H = 12\text{ V} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – common-mode rejection ratio in decibels: $\text{CMRR}_{dB} = 20\log_{10}\left(\frac{A_d}{A_{cm}}\right)$.

Step 1 – form the gain ratio: $\frac{A_d}{A_{cm}} = \frac{100}{0.01}$

Step 2 – evaluate the ratio: $\frac{100}{0.01} = 10000 = 10^4$

Step 3 – take the base-10 logarithm: $\log_{10}(10^4) = 4$

Step 4 – multiply by 20: $\text{CMRR}_{dB} = 20 \times 4 = 80$ dB

Final Answer: $\text{CMRR} = 80\text{ dB} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – op-amp integrator with a constant input: For a constant input the output ramps as $V_o(t) = -\frac{1}{RC} V_i\, t$.

Step 1 – form the time constant: $RC = (1 \times 10^6) \times (1 \times 10^{-6})$

$RC = 1$ s

Step 2 – write the output slope: $-\frac{1}{RC} V_i = -\frac{1}{1} \times 1 = -1$ V/s

Step 3 – multiply by the elapsed time: $V_o = -1 \times 2$

Step 4 – evaluate: $V_o = -2$ V

Why the other options are wrong:

- A, -1 V: uses $t = 1$ s instead of 2 s.
- B, $+2$ V: drops the inverting sign of the integrator.
- D, -4 V: uses $RC = 0.5$ s.

Final Answer: $V_o = -2$ V $\Rightarrow \boxed{\text{C}}$

$\boxed{\textbf{Answer: (C)}}$ Go Back to Q16

Q17.

Solution

Concept – corner frequency of a first-order filter: The -3 dB cut-off is set by the pole, $f_c = \frac{1}{2\pi RC}$.

Step 1 – convert the component values: $R = 1.6$ k$\Omega = 1.6 \times 10^3\ \Omega$

$C = 0.1\ \mu$F $= 0.1 \times 10^{-6}$ F $= 1 \times 10^{-7}$ F

Step 2 – form the product RC: $RC = (1.6 \times 10^3) \times (1 \times 10^{-7})$

$RC = 1.6 \times 10^{-4}$ s

Step 3 – multiply by 2π: $2\pi RC = 6.2832 \times 1.6 \times 10^{-4} = 1.005 \times 10^{-3}$

Step 4 – take the reciprocal: $f_c = \frac{1}{1.005 \times 10^{-3}}$

$f_c = 995$ Hz ≈ 1 kHz

Final Answer: $f_c \approx 1$ kHz $\Rightarrow \boxed{\text{B}}$

$\boxed{\textbf{Answer: (B)}}$ Go Back to Q17

Q18.

Solution

Concept – quiescent operating point of a CE stage: Kirchhoff's voltage law along the collector branch gives $V_{CE} = V_{CC} - I_C R_C$.

Step 1 – form the drop across the collector resistor: $I_C R_C = (2 \text{ mA}) \times (2 \text{ k}\Omega)$

Step 2 – evaluate that drop: $I_C R_C = 2 \times 10^{-3} \times 2 \times 10^3 = 4 \text{ V}$

Step 3 – subtract from the supply: $V_{CE} = 10 - 4$

Step 4 – evaluate: $V_{CE} = 6 \text{ V}$

Why the other options are wrong:

- A, 4 V: reports the resistor drop, not V_{CE}.
- C, 10 V: forgets the drop across R_C.
- D, 2 V: uses the wrong current or resistor value.

Final Answer: $V_{CE} = 6 \text{ V} \Rightarrow \boxed{\text{B}}$

Answer: (B) **Go Back to Q18**

Q19.

Solution

Concept – Boolean simplification by factoring: Factor the common literal and use $B + \bar{B} = 1$.

Step 1 – write the expression: $Y = AB + A\bar{B}$

Step 2 – factor out the common variable A: $Y = A\,(B + \bar{B})$

Step 3 – apply the complement law: $B + \bar{B} = 1$

Step 4 – substitute: $Y = A \times 1 = A$

Why the other options are wrong:

- B, B: the variable B cancels, it cannot be the answer.
- C, AB: keeps only one of the two product terms.
- D, $A + B$: comes from the different identity $A + \bar{A}B$.

Final Answer: $Y = A \Rightarrow \boxed{\text{A}}$

Answer: (A) **Go Back to Q19**

Q20.

Solution

Concept – hexadecimal-to-decimal conversion: Each hex digit is weighted by a power of 16: value $= d_1 \times 16^1 + d_0 \times 16^0$.

Step 1 – read the digits: For $(2F)_{16}$: the high digit is 2 and the low digit is $F = 15$.

Step 2 – weight the high digit: $2 \times 16 = 32$

Step 3 – weight the low digit: $15 \times 1 = 15$

Step 4 – add the weighted digits: $32 + 15 = 47$

Final Answer: $(2F)_{16} = 47 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q20

Q21.

Solution

Concept – Karnaugh-map grouping of the four corner cells: The four ones lie at the corners of the map. On a 4-variable K-map the corner cells are adjacent through the wrap-around and form one group of four.

Step 1 – list the minterm codes ($ABCD$): $m_0 = 0000$, $m_2 = 0010$, $m_8 = 1000$, $m_{10} = 1010$.

Step 2 – find the variables that stay constant: In all four codes $B = 0$ and $D = 0$; the variables A and C take both values.

Step 3 – keep only the constant literals: $B = 0 \Rightarrow \bar{B}$ and $D = 0 \Rightarrow \bar{D}$.

Step 4 – write the reduced product term: $F = \bar{B}\,\bar{D}$

Why the other options are wrong:

- B, $\bar{B}D$: wrong, all cells have $D = 0$.
- C, $B\bar{D}$: wrong, all cells have $B = 0$.
- D, $\bar{A}\bar{C}$: A and C both change, so they cannot appear.

Final Answer: $F = \bar{B}\,\bar{D} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q21

Q22.

Solution

Concept – fan-out of a logic gate: The fan-out is the largest number of standard inputs the output can drive, limited by the output-low current: fan-out $= \dfrac{I_{OL}}{I_{IL}}$.

Step 1 – list the current limits: $I_{OL} = 16$ mA (current the output can sink), $I_{IL} = 1.6$ mA (current one input demands).

Step 2 – form the ratio: fan-out $= \dfrac{16 \text{ mA}}{1.6 \text{ mA}}$

Step 3 – evaluate: fan-out $= 10$

Why the other options are wrong:

- A, 5 and D, 8: use wrong current values.
- C, 20: comes from dividing by 0.8 mA, not 1.6 mA.

Final Answer: fan-out $= 10 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – operation of a line decoder: A 3-to-8 decoder maps each of the $2^3 = 8$ input codes to exactly one output line, which it asserts while all the others stay inactive.

Step 1 – count the outputs: The decoder has 8 output lines (Y_0 to Y_7).

Step 2 – apply a single valid input code: For one address value, only the matching output goes active.

Step 3 – count the active outputs: Exactly 1 output is asserted at a time.

Why the other options are wrong:

- A, 8: is the total number of outputs, not those active at once.
- C, 3: is the number of address (select) lines.
- D, 0: a valid input always asserts one output (for an active decoder).

Final Answer: 1 output active $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q23

Q24.

Solution

Concept – number of states of a binary ripple counter: A chain of n toggling flip-flops (each with $T = 1$) cycles through 2^n distinct states.

Step 1 – count the flip-flops: $n = 5$.

Step 2 – raise 2 to that power: $2^n = 2^5$

Step 3 – evaluate: $2^5 = 32$

Why the other options are wrong:

- B, 31: is the highest count value, but the state 0 is also visited, giving 32 states.
- C, 16: corresponds to 4 flip-flops.
- D, 5: is just the number of flip-flops.

Final Answer: 32 states $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – aliasing when the Nyquist rate is violated: A tone of frequency f sampled below its Nyquist rate folds down to an apparent frequency $f_{alias} = |f - f_s|$ (for f between $f_s/2$ and f_s).

Step 1 – check for aliasing: $f = 7$ kHz and the Nyquist limit is $f_s/2 = 5$ kHz; since $7 > 5$, aliasing occurs.

Step 2 – form the difference: $f_{alias} = |f - f_s| = |7 - 10|$

Step 3 – evaluate: $f_{alias} = 3$ kHz

Why the other options are wrong:

- A, 7 kHz: would be the original frequency, which cannot survive at this sample rate.
- B, 10 kHz: is the sampling rate itself.
- D, 5 kHz: is the Nyquist limit, not the fold-down frequency.

Final Answer: $f_{alias} = 3$ kHz $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – d.c. gain of a transfer function: The d.c. (steady-state) gain is the value of $H(s)$ evaluated at $s = 0$.

Step 1 – write the transfer function: $H(s) = \dfrac{5}{s+5}$

Step 2 – substitute $s = 0$: $H(0) = \dfrac{5}{0+5}$

Step 3 – evaluate: $H(0) = \dfrac{5}{5} = 1$

Why the other options are wrong:

- A, 5: uses only the numerator and forgets to divide by the pole term.
- C, 0.2: inverts the correct ratio.
- D, 0: is the high-frequency limit $H(\infty)$, not the d.c. value.

Final Answer: $H(0) = 1 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – sum of a one-sided geometric sequence: For $|a| < 1$, $\displaystyle\sum_{n=0}^{\infty} a^n = \frac{1}{1-a}$.

Step 1 – identify the ratio: Here $x[n] = (0.25)^n u[n]$, so $a = 0.25$ and the sum starts at $n = 0$.

Step 2 – form the denominator: $1 - a = 1 - 0.25 = 0.75$

Step 3 – take the reciprocal: $\displaystyle\sum_{n=0}^{\infty} (0.25)^n = \frac{1}{0.75}$

Step 4 – evaluate: $\dfrac{1}{0.75} = 1.333$

Why the other options are wrong:

- A, 0.25: is just the first non-unity term.
- B, 4: uses $\dfrac{1}{a}$ instead of $\dfrac{1}{1-a}$.
- C, 0.75: reports the denominator, not the sum.

Final Answer: sum $= 1.333 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q27

Q28.

Solution

Concept – average power of a d.c.-plus-sinusoid signal: The powers of the constant part and the sinusoidal part add: $P = V_{dc}^2 + \dfrac{V_m^2}{2}$ (across $1\ \Omega$).

Step 1 – read the two parts: $V_{dc} = 2$ V and the sinusoid has amplitude $V_m = 3$ V.

Step 2 – compute the d.c. power: $V_{dc}^2 = 2^2 = 4$ W

Step 3 – compute the a.c. power: $\dfrac{V_m^2}{2} = \dfrac{3^2}{2} = \dfrac{9}{2} = 4.5$ W

Step 4 – add the two contributions: $P = 4 + 4.5 = 8.5$ W

Why the other options are wrong:

- A, 13 W: uses V_m^2 without the factor $\frac{1}{2}$.
- B, 4 W: keeps only the d.c. power.
- C, 4.5 W: keeps only the a.c. power.

Final Answer: $P = 8.5$ W $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

Q29.

Solution

Concept – length of a linear convolution: Convolving sequences of lengths N_1 and N_2 gives a result of length $N_1 + N_2 - 1$.

Step 1 – list the lengths: $N_1 = 5$, $N_2 = 4$.

Step 2 – add the lengths: $N_1 + N_2 = 5 + 4 = 9$

Step 3 – subtract one: $9 - 1 = 8$

Why the other options are wrong:

- A, 9: forgets to subtract one.
- B, 5 and D, 4: are just the individual input lengths.

Final Answer: length $= 8 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q29

Q30.

Solution

Concept – fold-down (alias) frequency: A component above the folding frequency $f_s/2$ appears at $f_{alias} = |f - f_s|$.

Step 1 – check for aliasing: $f = 5$ kHz and the folding frequency is $f_s/2 = 4$ kHz; since $5 > 4$, the component aliases.

Step 2 – form the difference: $f_{alias} = |5 - 8|$

Step 3 – evaluate: $f_{alias} = 3$ kHz

Why the other options are wrong:

- B, 5 kHz: would need $f \leq 4$ kHz to survive un-aliased.
- C, 8 kHz: is the sample rate.
- D, 13 kHz: adds instead of subtracting.

Final Answer: $f_{alias} = 3$ kHz $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q30

Q31.

Solution

Concept – reading ζ from a second-order characteristic equation: Match $s^2 + 2\zeta\omega_n s + \omega_n^2$ term by term.

Step 1 – identify ω_n^2: $\omega_n^2 = 100$, so $\omega_n = \sqrt{100} = 10$ rad/s.

Step 2 – match the middle coefficient: $2\zeta\omega_n = 2$

Step 3 – substitute $\omega_n = 10$: $2\zeta(10) = 2$

$20\zeta = 2$

Step 4 – solve for ζ: $\zeta = \dfrac{2}{20} = 0.1$

Why the other options are wrong:

- A, 1: would need the middle coefficient to be 20.
- B, 0.5: would need $\omega_n = 2$.
- C, 0.2: uses $\omega_n = 5$ by mistake.

Final Answer: $\zeta = 0.1 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q31

Q32.

Solution

Concept – Routh–Hurwitz array: Right-half-plane poles equal the number of sign changes in the first column of the Routh array.

Step 1 – write the first two rows from the coefficients of $s^3 + s^2 + 2s + 8$: Row s^3: 1, 2

Row s^2: 1, 8

Step 2 – compute the s^1 row entry: $\dfrac{(1)(2) - (1)(8)}{1} = \dfrac{2-8}{1} = -6$

Row s^1: -6

Step 3 – compute the s^0 row entry: Bringing down the last coefficient, Row s^0: 8

Step 4 – read the first column: $1,\ 1,\ -6,\ 8$

Step 5 – count the sign changes: $+ \to +$ (none), $+ \to -$ (one), $- \to +$ (two). There are 2 sign changes.

Step 6 – conclude: 2 poles lie in the right half-plane.

Final Answer: 2 RHP poles $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q32

Q33.

Solution

Concept – steady-state error to a ramp (Type-1 system): The velocity error constant is $K_v = \lim_{s\to 0} s\,G(s)$ and the ramp error is $e_{ss} = \dfrac{1}{K_v}$.

Step 1 – form $s\,G(s)$: $s\,G(s) = s \cdot \dfrac{20}{s(s+5)} = \dfrac{20}{s+5}$

Step 2 – take the limit $s \to 0$: $K_v = \dfrac{20}{0+5} = \dfrac{20}{5} = 4$

Step 3 – form the steady-state error: $e_{ss} = \dfrac{1}{K_v} = \dfrac{1}{4}$

Step 4 – evaluate: $e_{ss} = 0.25$

Why the other options are wrong:

- A, 0: is the step error of a Type-1 system, not the ramp error.
- B, infinite: applies to a Type-0 system driven by a ramp.
- C, 0.5: uses $K_v = 2$.

Final Answer: $e_{ss} = 0.25 \Rightarrow \boxed{\text{D}}$

$\boxed{\text{Answer: (D)}}$ Go Back to Q33

Q34.

Solution

Concept – Nyquist stability criterion: The number of clockwise encirclements N of the point $-1 + j0$ relates to the open-loop RHP poles P and closed-loop RHP poles Z by $Z = N + P$. For stability we need $Z = 0$.

Step 1 – insert the given open-loop pole count: Here $P = 0$, so $Z = N + 0 = N$.

Step 2 – impose the stability requirement: For a stable closed loop, $Z = 0$, hence $N = 0$.

Step 3 – interpret $N = 0$: Zero net encirclements: the Nyquist plot must not encircle the $-1 + j0$ point at all.

Step 4 – match with the sketch: The plotted locus stays to the right of $-1 + j0$, so it does not enclose it, confirming stability.

Why the other options are wrong:

- B and C (clockwise encirclements): each clockwise loop with $P = 0$ adds an unstable pole.
- D (counter-clockwise): with $P = 0$ this is impossible without an equal number of open-loop RHP poles.

Final Answer: zero encirclements $\Rightarrow \boxed{\text{A}}$

$\boxed{\text{Answer: (A)}}$ Go Back to Q34

Q35.

Solution

Concept – damped natural frequency: The oscillation frequency of the transient response is $\omega_d = \omega_n\sqrt{1 - \zeta^2}$.

Step 1 – square the damping ratio: $\zeta^2 = 0.6^2 = 0.36$

Step 2 – subtract from one: $1 - \zeta^2 = 1 - 0.36 = 0.64$

Step 3 – take the square root: $\sqrt{0.64} = 0.8$

Step 4 – multiply by the natural frequency: $\omega_d = 10 \times 0.8 = 8$ rad/s

Why the other options are wrong:

- A, 10 rad/s: is ω_n, the undamped value.

- C, 6 rad/s: uses $\sqrt{1-\zeta^2} = 0.6$ instead of 0.8.
- D, 4 rad/s: halves the natural frequency without justification.

Final Answer: $\omega_d = 8$ rad/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q35

Q36.

Solution

Concept – Friis' formula for cascaded noise factor: $F = F_1 + \dfrac{F_2 - 1}{G_1}$; the first stage dominates because later stages are divided by the front-end gain.

Step 1 – form the second-stage excess noise: $F_2 - 1 = 6 - 1 = 5$

Step 2 – divide by the first-stage gain: $\dfrac{F_2 - 1}{G_1} = \dfrac{5}{10} = 0.5$

Step 3 – add the first-stage noise factor: $F = F_1 + 0.5 = 2 + 0.5$

Step 4 – evaluate: $F = 2.5$

Why the other options are wrong:

- A, 8: adds the raw noise factors, ignoring the gain division.
- C, 6: takes F_2 alone.
- D, 2: drops the second-stage contribution entirely.

Final Answer: $F = 2.5 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – available thermal (Johnson) noise power: $N = kTB$, where k is Boltzmann's constant, T the temperature and B the noise bandwidth.

Step 1 – list the data: $k = 1.38 \times 10^{-23}$ J/K, $T = 290$ K, $B = 1$ MHz $= 1 \times 10^6$ Hz.

Step 2 – multiply k by T: $kT = (1.38 \times 10^{-23}) \times 290 = 4.00 \times 10^{-21}$

Step 3 – multiply by the bandwidth: $N = (4.00 \times 10^{-21}) \times (1 \times 10^6)$

Step 4 – combine the powers of ten: $N = 4.00 \times 10^{-15}$ W

Why the other options are wrong:

- A, 1.38×10^{-23} W: is just k, with no T or B.

- B, 4×10^{-21} W: is kT, forgetting the bandwidth.
- C, 4×10^{-9} W: mishandles the powers of ten.

Final Answer: $N = 4 \times 10^{-15}$ W $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – power ratio in decibels: $\text{SNR}_{dB} = 10 \log_{10}(\text{SNR})$.

Step 1 – write the ratio as a power of ten: $\text{SNR} = 1000 = 10^3$

Step 2 – take the base-10 logarithm: $\log_{10}(10^3) = 3$

Step 3 – multiply by 10**:** $\text{SNR}_{dB} = 10 \times 3 = 30$ dB

Why the other options are wrong:

- A, 10 dB and B, 20 dB: correspond to ratios of 10 and 100.
- D, 1000 dB: confuses the linear ratio with its decibel value.

Final Answer: $\text{SNR} = 30$ dB $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – sideband power fraction of an AM signal: Of the total power $P_t = P_c(1 + \frac{\mu^2}{2})$, the two sidebands carry $P_c\frac{\mu^2}{2}$, so the fraction is $\dfrac{\mu^2/2}{1 + \mu^2/2}$.

Step 1 – square the modulation index: $\mu^2 = 0.5^2 = 0.25$

Step 2 – halve it: $\dfrac{\mu^2}{2} = \dfrac{0.25}{2} = 0.125$

Step 3 – form the denominator: $1 + \dfrac{\mu^2}{2} = 1 + 0.125 = 1.125$

Step 4 – divide: $\text{fraction} = \dfrac{0.125}{1.125} = 0.111$

Step 5 – express as a percentage: $0.111 \times 100\% = 11.1\%$

Why the other options are wrong:

- A, 25%: is μ^2 read as a percentage.
- C, 50%: is the maximum sideband fraction, reached only at $\mu = 1$ (and even

then it is 33%).

- D, 33%: is the sideband fraction for full modulation $\mu = 1$, not $\mu = 0.5$.

Final Answer: $11.1\% \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q39

Q40.

Solution

Concept – entropy of a discrete memoryless source: $H = -\sum_i p_i \log_2 p_i$.

Step 1 – write the term for the first symbol ($p = 0.5$): $-0.5 \log_2(0.5) = -0.5 \times (-1) = 0.5$

Step 2 – write the term for the second symbol ($p = 0.25$): $-0.25 \log_2(0.25) = -0.25 \times (-2) = 0.5$

Step 3 – write the term for the third symbol ($p = 0.25$): $-0.25 \log_2(0.25) = 0.5$

Step 4 – add all three contributions: $H = 0.5 + 0.5 + 0.5$

Step 5 – evaluate: $H = 1.5$ bits/symbol

Why the other options are wrong:

- A, 2 bits/symbol: is the entropy of four equally likely symbols.
- D, 1 bit/symbol: ignores the two lower-probability symbols.
- B, 3 bits/symbol: exceeds $\log_2 3 \approx 1.585$, the maximum possible for three symbols.

Final Answer: $H = 1.5$ bits/symbol $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q40

Q41.

Solution

Concept – Carson's rule for FM bandwidth: $B = 2(\Delta f + f_m)$.

Step 1 – add the deviation and the modulating frequency: $\Delta f + f_m = 75 + 15 = 90$ kHz

Step 2 – multiply by two: $B = 2 \times 90$

Step 3 – evaluate: $B = 180$ kHz

Why the other options are wrong:

- B, 150 kHz: uses $2\Delta f$ only, dropping f_m.
- C, 75 kHz: reports the deviation alone.
- D, 90 kHz: forgets the factor of two.

Final Answer: $B = 180$ kHz $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – phase velocity in a dielectric: For a lossless non-magnetic medium the phase velocity is $u_p = \dfrac{c}{\sqrt{\varepsilon_r}}$.

Step 1 – take the square root of the permittivity: $\sqrt{\varepsilon_r} = \sqrt{4} = 2$

Step 2 – divide the speed of light by it: $u_p = \dfrac{3 \times 10^8}{2}$

Step 3 – evaluate: $u_p = 1.5 \times 10^8$ m/s

Why the other options are wrong:

- A, 3×10^8 m/s: is the free-space value; the wave slows in a dielectric.
- C, 0.75×10^8 m/s: divides by $\varepsilon_r = 4$ instead of $\sqrt{\varepsilon_r}$.
- D, 6×10^8 m/s: exceeds c, which is impossible.

Final Answer: $u_p = 1.5 \times 10^8$ m/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – polarization from two orthogonal field components: The tip of the resultant electric-field vector traces a shape set by the amplitude ratio and the phase difference of the two components.

Step 1 – note the amplitudes: E_x and E_y have equal amplitude.

Step 2 – note the phase difference: They are in quadrature, a 90° phase difference.

Step 3 – apply the polarization rule: Equal amplitudes and a 90° phase difference make the field vector rotate on a circle of constant magnitude.

Step 4 – name the polarization: This is circular polarization.

Why the other options are wrong:

- A, linear: needs the two components in phase (0° or 180°).
- B, elliptical: results from unequal amplitudes (with quadrature phase) or a phase other than 90°.
- D, unpolarized: describes random, incoherent fields, not a single deterministic plane wave.

Final Answer: circular polarization $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q43

Q44.

Solution

Concept – intrinsic impedance of a dielectric: For a lossless non-magnetic medium $\eta = \dfrac{\eta_0}{\sqrt{\varepsilon_r}}$.

Step 1 – take the square root of the permittivity: $\sqrt{\varepsilon_r} = \sqrt{4} = 2$

Step 2 – divide the free-space impedance by it: $\eta = \dfrac{377}{2}$

Step 3 – evaluate: $\eta = 188.5\ \Omega$

Why the other options are wrong:

- B, $377\ \Omega$: is the free-space value η_0 itself.
- C, $754\ \Omega$: multiplies by $\sqrt{\varepsilon_r}$ instead of dividing.
- D, $94\ \Omega$: divides by $\varepsilon_r = 4$ instead of $\sqrt{\varepsilon_r}$.

Final Answer: $\eta = 188.5\ \Omega \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q44

Q45.

Solution

Concept – wavelength in a dielectric: The wavelength shrinks with the refractive index, $\lambda = \dfrac{\lambda_0}{\sqrt{\varepsilon_r}}$.

Step 1 – take the square root of the permittivity: $\sqrt{\varepsilon_r} = \sqrt{4} = 2$

Step 2 – divide the free-space wavelength by it: $\lambda = \dfrac{1\text{ m}}{2}$

Step 3 – evaluate: $\lambda = 0.5\text{ m}$

Why the other options are wrong:

- A, 1 m: is the free-space wavelength, unchanged.
- B, 2 m: multiplies rather than divides.
- D, 0.25 m: divides by $\varepsilon_r = 4$ instead of $\sqrt{\varepsilon_r}$.

Final Answer: $\lambda = 0.5$ m $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – time-average power density of a plane wave: $S_{avg} = \dfrac{E_0^2}{2\eta_0}$, where E_0 is the peak electric-field amplitude.

Step 1 – square the field amplitude: $E_0^2 = 377^2 = 142129$

Step 2 – form the denominator: $2\eta_0 = 2 \times 377 = 754$

Step 3 – divide: $S_{avg} = \dfrac{142129}{754}$

Step 4 – evaluate (note $S_{avg} = E_0/2$ since $E_0 = \eta_0$): $S_{avg} = 188.5$ W/m^2

Why the other options are wrong:

- A, 377 W/m^2: forgets the factor of 2 (that would be E_0^2/η_0).
- C, 94.25 W/m^2: uses $4\eta_0$ in the denominator.
- D, 754 W/m^2: mishandles the factor entirely.

Final Answer: $S_{avg} = 188.5$ W/m^2 $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q46

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	A	3	D	4	D	5	A
6	D	7	B	8	A	9	A	10	D
11	C	12	C	13	A	14	D	15	D
16	C	17	B	18	B	19	A	20	B
21	A	22	B	23	B	24	A	25	C
26	B	27	D	28	D	29	C	30	A
31	D	32	C	33	D	34	A	35	B
36	B	37	D	38	C	39	B	40	C
41	A	42	B	43	C	44	A	45	C
46	B								