GATE Electronics and Communication Engineering

Sample Paper – 5

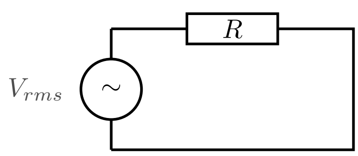
Duration: 128 Minutes **Maximum Marks: 72**

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. A sinusoidal source of r.m.s. voltage 20 V is applied across a pure resistor of 10 Ω, as shown. The average (real) power dissipated in the resistor is: [1 mark]



(A) 20 W

(B) 40 W

(C) 80 W

(D) 4 W

Q2. A series RL branch has resistance $R = 3\ \Omega$ and inductive reactance $X_L = 4\ \Omega$ at the operating frequency. The magnitude of the branch impedance $|Z| = \sqrt{R^2 + X_L^2}$ is: **[1 mark]**

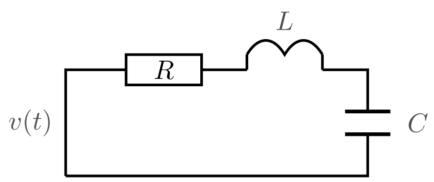
(A) $7\ \Omega$

(B) $1\ \Omega$

(C) $3.5\ \Omega$

(D) $5\ \Omega$

Q3. A series RLC circuit has $L = 2$ mH and $C = 20\ \mu$F, as shown. The undamped natural (resonant) angular frequency $\omega_0 = 1/\sqrt{LC}$ of the circuit is: **[1 mark]**



(A) 2500 rad/s

(B) 5000 rad/s

(C) 10000 rad/s

(D) 500 rad/s

Q4. An a.c. load draws current at a complex impedance $Z = 8 + j6\ \Omega$. Its power factor, p.f. $= R/|Z|$, is: **[1 mark]**

(A) 0.6

(B) 0.1

(C) 1.0

(D) 0.8

Q5. An ideal capacitor of $C = 100\ \mu\text{F}$ is driven by a sinusoidal source of angular frequency $\omega = 1000$ rad/s, as shown. The magnitude of the capacitive reactance $X_C = 1/(\omega C)$ is: **[1 mark]**

(A) $1\ \Omega$

(B) $100\ \Omega$

(C) $0.1\ \Omega$

(D) $10\ \Omega$

Q6. A source-free series RC circuit has $R = 5\ \text{k}\Omega$ and $C = 4\ \mu\text{F}$. The time constant $\tau = RC$ of its natural (transient) response is: **[1 mark]**

(A) 5 ms

(B) 50 ms

(C) 20 ms

(D) 200 ms

Electronic Devices

Q7. A silicon sample is uniformly doped p-type with acceptor concentration $N_a = 2 \times 10^{17}\ \text{cm}^{-3}$. Taking $n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$ and full ionisation, the equilibrium electron (minority-carrier) concentration is nearest to: **[1 mark]**

(A) $1.1 \times 10^{3}\ \text{cm}^{-3}$

(B) $2 \times 10^{17}\ \text{cm}^{-3}$

(C) $2.25 \times 10^{20}\ \text{cm}^{-3}$

(D) $1.5 \times 10^{10}\ \text{cm}^{-3}$

Q8. The thermal voltage $V_T = kT/q$ of a semiconductor at room temperature ($T = 300$ K) is closest to: **[1 mark]**

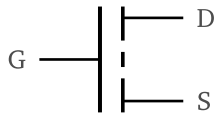
(A) 300 mV

(B) 100 mV

(C) 1 mV

(D) 26 mV

Q9. An n-channel enhancement MOSFET has threshold voltage $V_t = 1$ V. It is biased with $V_{GS} = 2$ V and $V_{DS} = 3$ V, as shown. Since $V_{DS} > (V_{GS} - V_t)$, the device operates in the: **[1 mark]**



(A) cut-off region

(B) triode (linear) region

(C) saturation region

(D) breakdown region

Q10. An npn BJT operating in the active region has a common-emitter current gain $\beta = 100$ and a base current $I_B = 20$ μA. The collector current $I_C = \beta I_B$ is: **[1 mark]**

(A) 200 μA

(B) 2 mA

(C) 20 mA

(D) 0.2 mA

Q11. In an n-type silicon sample the electron mobility is $\mu_n = 1000$ cm^2/V $\cdot$ s. Using the Einstein relation $D_n = \mu_n V_T$ with $V_T = 26$ mV at room temperature, the electron diffusion coefficient D_n is nearest to: **[1 mark]**

(A) 1000 cm^2/s

(B) $0.026\ \text{cm}^2/\text{s}$

(C) $260\ \text{cm}^2/\text{s}$

(D) $26\ \text{cm}^2/\text{s}$

Analog Circuits

Q12. An ideal-op-amp inverting amplifier has $R_1 = 22\ \text{k}\Omega$ and feedback resistor $R_f = 220\ \text{k}\Omega$. The magnitude of the closed-loop voltage gain $|V_o/V_i| = R_f/R_1$ is: **[1 mark]**

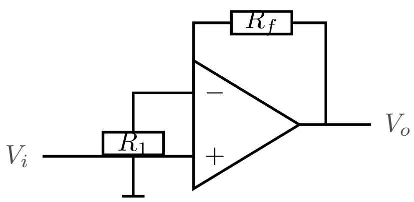
(A) 10

(B) 11

(C) 0.1

(D) 100

Q13. For the ideal-op-amp non-inverting amplifier shown, $R_1 = 25\ \text{k}\Omega$ (from the inverting node to ground) and $R_f = 100\ \text{k}\Omega$ (feedback). The closed-loop voltage gain $V_o/V_i = 1 + R_f/R_1$ is: **[1 mark]**



(A) 4

(B) 5

(C) 0.2

(D) 6

Q14. A BJT in its small-signal model is biased at a quiescent collector current $I_C = 2$ mA. Taking $V_T = 25$ mV, the transconductance $g_m = I_C/V_T$ of the device is: **[1 mark]**

(A) 80 mA/V

(B) 40 mA/V

(C) 8 mA/V

(D) 25 mA/V

Q15. In the hybrid-π small-signal model of a BJT with $\beta = 100$ biased at $I_C = 1$ mA (so $g_m = I_C/V_T$ with $V_T = 25$ mV), the small-signal input resistance $r_\pi = \beta/g_m$ is: **[1 mark]**

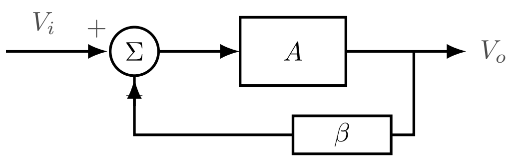
(A) 1.25 kΩ

(B) 2.5 kΩ

(C) 25 kΩ

(D) 250 Ω

Q16. An amplifier with open-loop gain $A = 10000$ is placed in a negative-feedback loop with feedback factor $\beta = 0.01$, as shown. The closed-loop gain $A_f = A/(1 + A\beta)$ is nearest to: **[1 mark]**



(A) 99

(B) 100

(C) 9.9

(D) 10000

Q17. An amplifier has an open-loop -3 dB bandwidth of 10 kHz. When negative feedback is applied with a loop factor $(1 + A\beta) = 20$, the closed-loop bandwidth (which widens by the same factor) becomes: **[1 mark]**

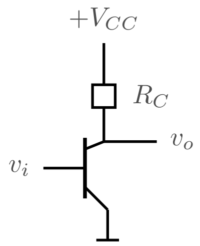
(A) 200 kHz

(B) 20 kHz

(C) 0.5 kHz

(D) 10 kHz

Q18. The common-emitter BJT amplifier shown operates at a quiescent collector current $I_C = 1$ mA with a collector resistor $R_C = 2.5$ kΩ. Taking $V_T = 25$ mV and neglecting r_o, the magnitude of the small-signal voltage gain $|A_v| = g_m R_C$ is: **[1 mark]**



(A) 40

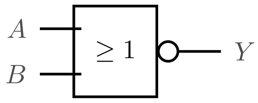
(B) 250

(C) 100

(D) 25

Digital Circuits

Q19. For the two-input gate shown, the output equals the logical OR of the inputs followed by an inverter (a NOR gate). By De Morgan's theorem $\overline{A+B}$ is equal to: **[1 mark]**



(A) $A + B$

(B) $A \cdot B$

(C) $\bar{A} + \bar{B}$

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

Q20. A JK flip-flop has both inputs tied high, $J = K = 1$. On every active clock edge the output Q: **[1 mark]**

(A) holds its previous value

(B) toggles ($Q_{next} = \bar{Q}$)

(C) is set to 1

(D) is reset to 0

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 fall on 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) $\bar{B}D$

(B) $B\bar{D}$

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

(D) BD

Q22. A Johnson (twisted-ring) counter is built from 4 flip-flops. The number of distinct states in its counting sequence is $2n$, so it is: **[2 marks]**

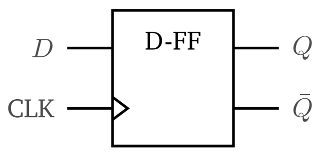
(A) 4

(B) 8

(C) 16

(D) 15

Q23. A modulo-60 synchronous counter (as used in the seconds stage of a digital clock) is built from edge-triggered D flip-flops, one of which is shown. The minimum number of flip-flops needed so that $2^n \geq 60$ is: **[2 marks]**



(A) 6

(B) 5

(C) 60

(D) 7

Q24. A flip-flop based register has a propagation delay $t_{pd} = 6$ ns and a set-up time $t_{su} = 2$ ns. The maximum clock frequency, $f_{max} = 1/(t_{pd} + t_{su})$, is:[2 marks]

(A) 125 MHz

(B) 100 MHz

(C) 62.5 MHz

(D) 250 MHz

Signals and Systems

Q25. The one-sided Laplace transform of the causal signal $x(t) = e^{-3t}u(t)$ is:[2 marks]

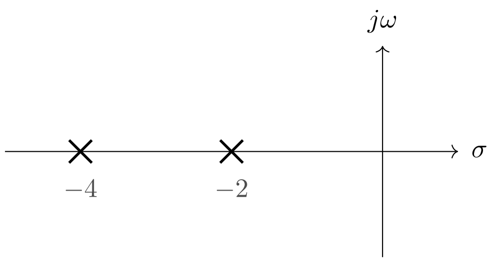
(A) $\frac{1}{s}$

(B) $\frac{1}{s-3}$

(C) $\frac{1}{s+3}$

(D) $\frac{3}{s}$

Q26. A stable LTI system has the transfer function $H(s) = \frac{20}{s^2 + 6s + 8}$, whose pole–zero plot is shown (poles marked $\times$). The d.c. gain $H(0)$ of the system is: [2 marks]



(A) 20

(B) 2.5

(C) 0.4

(D) 5

Q27. A causal signal has Laplace transform $X(s) = \dfrac{10}{s(s+5)}$. Using the final value theorem $x(\infty) = \lim_{s\to 0} sX(s)$, the steady-state value $x(\infty)$ is: **[2 marks]**

(A) 2

(B) 10

(C) 0

(D) 5

Q28. The Laplace transform of the unit-ramp signal $x(t) = t\,u(t)$ is: **[2 marks]**

(A) $\dfrac{1}{s^2}$

(B) $\dfrac{1}{s}$

(C) $\dfrac{2}{s^3}$

(D) s

Q29. Two finite-length discrete sequences of lengths 6 and 5 samples respectively are linearly convolved. The length (number of samples) of the resulting sequence, $L_1 + L_2 - 1$, is: **[2 marks]**

(A) 11

(B) 30

(C) 6

(D) 10

Q30. The one-sided Laplace transform of the causal cosine $x(t) = \cos(\omega_0 t)\,u(t)$ is: **[2 marks]**

(A) $\dfrac{\omega_0}{s^2+\omega_0^2}$

(B) $\dfrac{s}{s^2+\omega_0^2}$

(C) $\dfrac{1}{s+\omega_0}$

(D) $\dfrac{s}{s^2-\omega_0^2}$

Control Systems

Q31. A standard second-order system has the characteristic equation $s^2+4s+25=0$. The damping ratio ζ of the system is: **[2 marks]**

(A) 1

(B) 0.5

(C) 0.4

(D) 0.8

Q32. A unity-feedback system has open-loop transfer function $G(s)H(s) = \dfrac{K}{s(s+2)(s+4)}$. The number of branches of its root locus (equal to the number of open-loop poles) is: **[2 marks]**

(A) 1

(B) 2

(C) 3

(D) 0

Q33. For the open-loop transfer function $G(s)H(s) = \dfrac{K}{s(s+2)(s+4)}$ (poles at $0, -2, -4$ and no finite zeros), the centroid of the root-locus asymptotes, $\sigma_a = \dfrac{\sum \text{poles} - \sum \text{zeros}}{P-Z}$, is: **[2 marks]**

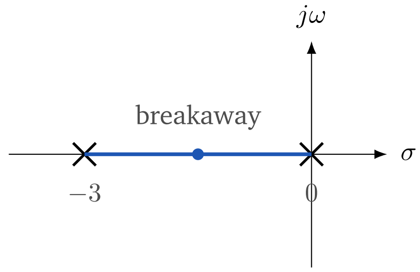
(A) 0

(B) -1

(C) -3

(D) -2

Q34. The root locus of $G(s)H(s) = \dfrac{K}{s(s+3)}$ (poles at 0 and -3) lies on the real axis between the two poles, as sketched. The breakaway point, found from $dK/ds = 0$ with $K = -s(s+3)$, is: **[2 marks]**



(A) 0

(B) -3

(C) -1.5

(D) -0.75

Q35. A type-1 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 $e_{ss} = 1/K_v$ with $K_v = \lim_{s\to 0} sG(s)$. This error is: **[2 marks]**

(A) 0

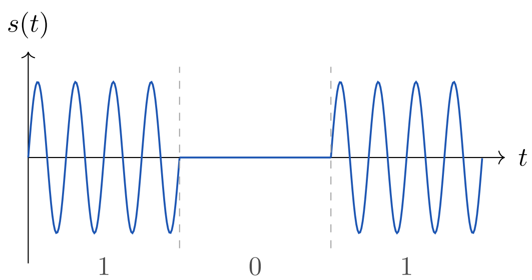
(B) 0.25

(C) 1

(D) 4

Communications

Q36. In the digitally modulated waveform shown, the carrier is transmitted at full amplitude for a data bit 1 and is switched off for a data bit 0. This scheme is called: **[2 marks]**



(A) frequency-shift keying (FSK)

(B) amplitude-shift keying (ASK)

(C) phase-shift keying (PSK)

(D) quadrature amplitude modulation (QAM)

Q37. 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 is $B = 2(\Delta f + f_m)$. This bandwidth is: **[2 marks]**

(A) 180 kHz

(B) 90 kHz

(C) 150 kHz

(D) 75 kHz

Q38. A signal is sampled at $f_s = 10$ kHz and each sample is encoded with 64 uniform quantization levels in a PCM system. The output bit rate, $R_b = f_s \log_2 L$, is: **[2 marks]**

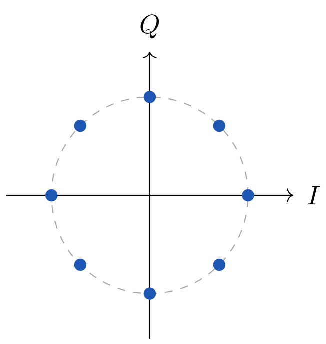
(A) 10 kbps

(B) 640 kbps

(C) 60 kbps

(D) 6 kbps

Q39. A digital modulation scheme uses the 8-point constellation shown, with the points spaced equally around a circle (8-PSK). The number of bits carried per transmitted symbol, $\log_2 M$, is: **[2 marks]**



(A) 8

(B) 1

(C) 2

(D) 3

Q40. A discrete memoryless source emits four symbols with probabilities $\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{8}$. The entropy of the source, $H = \sum p_i \log_2(1/p_i)$, is: **[2 marks]**

(A) 2 bits/symbol

(B) 1 bit/symbol

(C) 1.75 bits/symbol

(D) 3 bits/symbol

Q41. A communication channel of bandwidth 4 kHz has a signal-to-noise ratio of 15 (as a power ratio). By the Shannon–Hartley law $C = B \log_2(1 + \text{SNR})$, the channel capacity is: **[2 marks]**

(A) 16 kbps

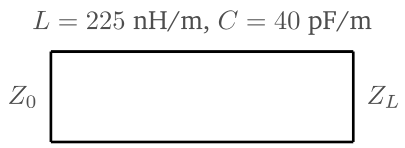
(B) 4 kbps

(C) 8 kbps

(D) 20 kbps

Electromagnetics

Q42. A lossless transmission line has distributed inductance $L = 225$ nH/m and distributed capacitance $C = 40$ pF/m, as indicated. Its characteristic impedance $Z_0 = \sqrt{L/C}$ is: **[2 marks]**



(A) 50 Ω

(B) 75 Ω

(C) 100 Ω

(D) $37.5\ \Omega$

Q43. A transmission line of characteristic impedance $Z_0 = 75\ \Omega$ is terminated in a load $Z_L = 25\ \Omega$. Using $\Gamma = (Z_L - Z_0)/(Z_L + Z_0)$ and VSWR $= (1 + |\Gamma|)/(1 - |\Gamma|)$, the voltage standing-wave ratio on the line is: **[2 marks]**

(A) 3

(B) 0.5

(C) 2

(D) 1

Q44. On a transmission line the measured voltage standing-wave ratio is VSWR $= 2$. The magnitude of the reflection coefficient, $|\Gamma| = (\text{VSWR}-1)/(\text{VSWR}+1)$, is: **[2 marks]**

(A) 1

(B) 0.5

(C) 0.667

(D) 0.333

Q45. A uniform plane wave of frequency 1.5 GHz propagates in free space. Its wavelength $\lambda = c/f$ (with $c = 3 \times 10^8$ m/s) is: **[2 marks]**

(A) 10 cm

(B) 30 cm

(C) 15 cm

(D) 20 cm

Q46. A quarter-wave transformer is to match a $50\ \Omega$ load to a $100\ \Omega$ line. The required characteristic impedance of the quarter-wave section, $Z_0' = \sqrt{Z_{line} Z_L}$, is nearest to: **[2 marks]**

(A) $50\ \Omega$

(B) $150\ \Omega$

(C) $70.7\ \Omega$

(D) $100\ \Omega$

Detailed Solutions

Q1.

Solution

Concept – average power in a resistor from r.m.s. voltage: For a sinusoid across a resistor the average power is $P = \dfrac{V_{rms}^2}{R}$.

Step 1 – list the data: $V_{rms} = 20$ V, $R = 10\ \Omega$.

Step 2 – square the r.m.s. voltage: $V_{rms}^2 = 20^2 = 400$

Step 3 – divide by the resistance: $P = \dfrac{400}{10}$

Step 4 – evaluate: $P = 40$ W

Step 5 – note on r.m.s.: Using the r.m.s. value directly gives the true average power; using the peak value would overstate it by a factor of two.

Final Answer: $P = 40 \text{ W} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – impedance magnitude of a series RL branch: $|Z| = \sqrt{R^2 + X_L^2}$.

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

Step 2 – square each term: $R^2 = 3^2 = 9$

$X_L^2 = 4^2 = 16$

Step 3 – add the squares: $9 + 16 = 25$

Step 4 – take the square root: $|Z| = \sqrt{25} = 5\ \Omega$

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

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – resonant frequency of a series RLC circuit: The undamped natural frequency is $\omega_0 = \dfrac{1}{\sqrt{LC}}$.

Step 1 – convert the values to base units: $L = 2 \text{ mH} = 2 \times 10^{-3}$ H

$C = 20\ \mu\text{F} = 20 \times 10^{-6}$ F

Step 2 – form the product LC: $LC = (2 \times 10^{-3}) \times (20 \times 10^{-6})$

$LC = 40 \times 10^{-9} = 4 \times 10^{-8}$

Step 3 – take the square root: $\sqrt{LC} = \sqrt{4 \times 10^{-8}} = 2 \times 10^{-4}$

Step 4 – invert: $\omega_0 = \dfrac{1}{2 \times 10^{-4}}$

$\omega_0 = 5000 \text{ rad/s}$

Final Answer: $\omega_0 = 5000 \text{ rad/s} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q3

Q4.

Solution

Concept – power factor of a complex load: The power factor is the cosine of the impedance angle, equal to $\dfrac{R}{|Z|}$.

Step 1 – identify the parts of $Z = 8 + j6$: $R = 8\ \Omega$, $X = 6\ \Omega$.

Step 2 – find the magnitude of Z: $|Z| = \sqrt{8^2 + 6^2} = \sqrt{64 + 36} = \sqrt{100} = 10\ \Omega$

Step 3 – form the ratio $R/|Z|$: $\text{p.f.} = \dfrac{8}{10}$

Step 4 – evaluate: $\text{p.f.} = 0.8$ (lagging, since the load is inductive)

Final Answer: $\text{p.f.} = 0.8 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

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

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

Step 2 – form the product ωC: $\omega C = 1000 \times (1 \times 10^{-4})$

$\omega C = 0.1$

Step 3 – take the reciprocal: $X_C = \dfrac{1}{0.1}$

Step 4 – evaluate: $X_C = 10\ \Omega$

Final Answer: $X_C = 10\ \Omega \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – time constant of an RC circuit: For a first-order RC circuit the time constant is $\tau = RC$.

Step 1 – convert the values to base units: $R = 5\ \mathrm{k}\Omega = 5 \times 10^3\ \Omega$

$C = 4\ \mu\mathrm{F} = 4 \times 10^{-6}\ \mathrm{F}$

Step 2 – multiply: $\tau = (5 \times 10^3) \times (4 \times 10^{-6})$

Step 3 – combine the powers of ten: $\tau = 20 \times 10^{-3}$

$\tau = 0.02\ \mathrm{s} = 20\ \mathrm{ms}$

Final Answer: $\tau = 20\ \mathrm{ms} \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – mass-action law in a doped semiconductor: At equilibrium $n\,p = n_i^2$. For a p-type sample $p \approx N_a$, so the minority electron concentration is $n = \dfrac{n_i^2}{N_a}$.

Step 1 – square the intrinsic concentration: $n_i^2 = (1.5 \times 10^{10})^2$

$n_i^2 = 2.25 \times 10^{20}\ \mathrm{cm}^{-6}$

Step 2 – take the majority-carrier concentration: $p \approx N_a = 2 \times 10^{17}\ \mathrm{cm}^{-3}$

Step 3 – divide to get the electron concentration: $n = \dfrac{2.25 \times 10^{20}}{2 \times 10^{17}}$

Step 4 – combine the powers of ten: $n = 1.125 \times 10^3\ \mathrm{cm}^{-3} \approx 1.1 \times 10^3\ \mathrm{cm}^{-3}$

Final Answer: $n \approx 1.1 \times 10^3\ \mathrm{cm}^{-3} \Rightarrow \boxed{\mathrm{A}}$

Answer: (A) Go Back to Q7

Q8.

Solution

Concept – thermal voltage: The thermal voltage is $V_T = \dfrac{kT}{q}$, with k Boltzmann's constant, T the absolute temperature and q the electronic charge.

Step 1 – list the constants: $k = 1.38 \times 10^{-23}$ J/K, $T = 300$ K, $q = 1.6 \times 10^{-19}$ C.

Step 2 – form the numerator kT: $kT = (1.38 \times 10^{-23}) \times 300 = 4.14 \times 10^{-21}$ J

Step 3 – divide by q: $V_T = \dfrac{4.14 \times 10^{-21}}{1.6 \times 10^{-19}}$

Step 4 – evaluate: $V_T = 25.9 \times 10^{-3}$ V ≈ 26 mV

Final Answer: $V_T \approx 26$ mV $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q8

Q9.

Solution

Concept – region of operation of an enhancement MOSFET: With $V_{GS} > V_t$ the channel is formed; the device is in saturation if $V_{DS} \geq (V_{GS} - V_t)$ and in the triode region if $V_{DS} < (V_{GS} - V_t)$.

Step 1 – check that the channel exists: $V_{GS} = 2$ V and $V_t = 1$ V, so $V_{GS} > V_t$ and a channel is present (device is on).

Step 2 – compute the overdrive voltage: $V_{GS} - V_t = 2 - 1 = 1$ V

Step 3 – compare V_{DS} with the overdrive: $V_{DS} = 3$ V, and $3 > 1$, so $V_{DS} > (V_{GS} - V_t)$.

Step 4 – match to the region rule: $V_{DS} \geq (V_{GS} - V_t)$ pins the device in the **saturation** region.

Why the other options are wrong:

- A, cut-off: needs $V_{GS} < V_t$, but here the channel is on.
- B, triode: needs $V_{DS} < (V_{GS} - V_t)$, which is not the case.
- D, breakdown: needs a junction voltage beyond its rated limit, not indicated here.

Final Answer: saturation region $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – collector current of a BJT in the active region: $I_C = \beta I_B$, where β is the common-emitter current gain.

Step 1 – convert the base current: $I_B = 20\ \mu\text{A} = 20 \times 10^{-6}$ A

Step 2 – multiply by β: $I_C = 100 \times (20 \times 10^{-6})$

Step 3 – evaluate: $I_C = 2000 \times 10^{-6}$ A $= 2 \times 10^{-3}$ A

$I_C = 2$ mA

Final Answer: $I_C = 2 \text{ mA} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – Einstein relation: The diffusion coefficient and mobility are linked by $D_n = \mu_n V_T$.

Step 1 – list the data: $\mu_n = 1000 \text{ cm}^2/\text{V}\cdot\text{s}$, $V_T = 26 \text{ mV} = 0.026 \text{ V}$.

Step 2 – multiply mobility by the thermal voltage: $D_n = 1000 \times 0.026$

Step 3 – evaluate: $D_n = 26 \text{ cm}^2/\text{s}$

Step 4 – check the units: $(\text{cm}^2/\text{V}\cdot\text{s}) \times (\text{V}) = \text{cm}^2/\text{s}$, as required for a diffusion coefficient.

Final Answer: $D_n = 26 \text{ cm}^2/\text{s} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q11

Q12.

Solution

Concept – gain of an inverting op-amp: For an ideal inverting amplifier $\frac{V_o}{V_i} = -\frac{R_f}{R_1}$, so the magnitude is $\frac{R_f}{R_1}$.

Step 1 – list the resistor values: $R_f = 220 \text{ k}\Omega$, $R_1 = 22 \text{ k}\Omega$.

Step 2 – form the ratio: $|A_v| = \frac{220 \text{ k}\Omega}{22 \text{ k}\Omega}$

Step 3 – evaluate: $|A_v| = 10$

Final Answer: $|A_v| = 10 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – gain of a non-inverting op-amp: For an ideal non-inverting amplifier $\frac{V_o}{V_i} = 1 + \frac{R_f}{R_1}$.

Step 1 – form the resistor ratio: $\frac{R_f}{R_1} = \frac{100\ \text{k}\Omega}{25\ \text{k}\Omega} = 4$

Step 2 – add one: $A_v = 1 + 4$

Step 3 – evaluate: $A_v = 5$

Why the other options are wrong:

- A, 4: is just R_f/R_1; it forgets the "$+1$" of the non-inverting topology.
- C, 0.2: inverts the ratio.
- D, 6: adds two instead of one.

Final Answer: $A_v = 5 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – transconductance in the BJT small-signal model: $g_m = \frac{I_C}{V_T}$.

Step 1 – list the data: $I_C = 2\ \text{mA} = 2 \times 10^{-3}\ \text{A}$, $V_T = 25\ \text{mV} = 25 \times 10^{-3}\ \text{V}$.

Step 2 – form the ratio: $g_m = \frac{2 \times 10^{-3}}{25 \times 10^{-3}}$

Step 3 – simplify: $g_m = \frac{2}{25} = 0.08\ \text{A/V}$

Step 4 – express in mA/V: $g_m = 80\ \text{mA/V}$

Final Answer: $g_m = 80\ \text{mA/V} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – input resistance in the hybrid-π model: $r_\pi = \frac{\beta}{g_m}$, where $g_m = \frac{I_C}{V_T}$.

Step 1 – compute the transconductance: $g_m = \frac{I_C}{V_T} = \frac{1\ \text{mA}}{25\ \text{mV}} = 0.04\ \text{A/V}$

Step 2 – form $r_\pi = \beta/g_m$**:** $r_\pi = \dfrac{100}{0.04}$

Step 3 – evaluate: $r_\pi = 2500\ \Omega$

Step 4 – express in kΩ**:** $r_\pi = 2.5\ \text{k}\Omega$

Step 5 – cross-check: Equivalently $r_\pi = \dfrac{\beta V_T}{I_C} = \dfrac{100 \times 25\ \text{mV}}{1\ \text{mA}} = 2.5\ \text{k}\Omega$, which agrees.

Final Answer: $r_\pi = 2.5\ \text{k}\Omega \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q15

Q16.

Solution

Concept – closed-loop gain with negative feedback: $A_f = \dfrac{A}{1 + A\beta}$.

Step 1 – form the loop gain: $A\beta = 10000 \times 0.01 = 100$

Step 2 – form the denominator: $1 + A\beta = 1 + 100 = 101$

Step 3 – divide: $A_f = \dfrac{10000}{101}$

Step 4 – evaluate: $A_f = 99.01 \approx 99$

Step 5 – interpret: The ideal value $1/\beta = 100$ is only reached for infinite loop gain; the finite loop gain here pulls A_f slightly below 100.

Final Answer: $A_f \approx 99 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – bandwidth extension by negative feedback: Negative feedback widens the bandwidth by the same factor $(1 + A\beta)$ by which it reduces the gain: $\text{BW}_{cl} = \text{BW}_{ol} \times (1 + A\beta)$.

Step 1 – list the data: $\text{BW}_{ol} = 10$ kHz, $(1 + A\beta) = 20$.

Step 2 – multiply: $\text{BW}_{cl} = 10\ \text{kHz} \times 20$

Step 3 – evaluate: $\text{BW}_{cl} = 200\ \text{kHz}$

Final Answer: $\text{BW}_{cl} = 200\ \text{kHz} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – voltage gain of a common-emitter stage: The transconductance is $g_m = \dfrac{I_C}{V_T}$ and the magnitude of the gain is $|A_v| = g_m R_C$.

Step 1 – compute the transconductance: $g_m = \dfrac{I_C}{V_T} = \dfrac{1\text{ mA}}{25\text{ mV}}$

$g_m = 0.04\text{ A/V} = 40\text{ mA/V}$

Step 2 – convert the collector resistor: $R_C = 2.5\text{ k}\Omega = 2500\ \Omega$

Step 3 – form the gain: $|A_v| = g_m R_C = 0.04 \times 2500$

Step 4 – evaluate: $|A_v| = 100$

Final Answer: $|A_v| = 100 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – De Morgan's theorem: The complement of a sum equals the product of the complements: $\overline{A+B} = \bar{A} \cdot \bar{B}$.

Step 1 – start from the NOR expression: $Y = \overline{A+B}$

Step 2 – apply De Morgan (break the bar over the OR, change OR to AND): $\overline{A+B} = \bar{A} \cdot \bar{B}$

Step 3 – verify with a truth-table check: $Y = 1$ only when both $A = 0$ and $B = 0$; the product $\bar{A}\bar{B}$ is 1 exactly in that same single case, so the two agree.

Why the other options are wrong:

- A, $A + B$: is the OR before inversion, not the NOR.
- B, $A \cdot B$: is the AND function.
- C, $\bar{A} + \bar{B}$: is the NAND ($\overline{A \cdot B}$), a different gate.

Final Answer: $\overline{A+B} = \bar{A} \cdot \bar{B} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q19

Q20.

Solution

Concept – JK flip-flop with $J = K = 1$: The characteristic equation of a JK flip-flop is $Q_{next} = J\bar{Q} + \bar{K}Q$.

Step 1 – substitute $J = 1$ and $K = 1$: $Q_{next} = (1)\bar{Q} + \overline{(1)}\,Q$

Step 2 – simplify $\bar{K} = \bar{1} = 0$: $Q_{next} = \bar{Q} + 0 \cdot Q$

Step 3 – reduce: $Q_{next} = \bar{Q}$

Step 4 – interpret: Each clock edge makes the output the complement of its present value, i.e. the output **toggles**.

Why the other options are wrong:

- A, holds: is the $J = K = 0$ case.
- C, set: is the $J = 1, K = 0$ case.
- D, reset: is the $J = 0, K = 1$ case.

Final Answer: the output toggles $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q20

Q21.

Solution

Concept – grouping ones on a Karnaugh map: Ones may be grouped across the map edges (the map wraps around); the four corner cells form one group of four.

Step 1 – place the minterms: $\sum m(0, 2, 8, 10)$ fills the four corner cells: $(AB{=}00, CD{=}00)$, $(AB{=}00, CD{=}10)$, $(AB{=}10, CD{=}00)$ and $(AB{=}10, CD{=}10)$.

Step 2 – recognise the wrap-around group: Because the map is toroidal, the top and bottom rows are adjacent and the left and right columns are adjacent, so the four corners are a single group of four.

Step 3 – find which variables stay constant: Over these corners $B = 0$ (rows 00 and 10 both have $B = 0$) and $D = 0$ (columns 00 and 10 both have $D = 0$), while A and C each take both values.

Step 4 – keep only the constant literals: The constant literals are $\bar{B}$ and $\bar{D}$, so the group is $\bar{B}\,\bar{D}$.

Step 5 – verify: $\bar{B}\,\bar{D}$ covers every cell with $B = 0$ and $D = 0$, namely $m0, m2, m8, m10$, exactly the given ones.

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

Answer: (C) Go Back to Q21

Q22.

Solution

Concept – number of states of a Johnson counter: A Johnson (twisted-ring) counter made of n flip-flops steps through $2n$ distinct states before repeating.

Step 1 – list the data: $n = 4$ flip-flops.

Step 2 – apply the $2n$ rule: Number of states $= 2 \times 4$

Step 3 – evaluate: $= 8$ states

Step 4 – contrast with a ring counter: A plain ring counter of 4 flip-flops gives only 4 states; the feedback inversion of the Johnson counter doubles this to 8.

Final Answer: 8 states $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – number of flip-flops for a given modulus: n flip-flops provide 2^n states; the smallest n with $2^n \geq M$ is required.

Step 1 – write the requirement for a mod-60 counter: $2^n \geq 60$

Step 2 – test $n = 5$: $2^5 = 32$, and $32 < 60$, so 5 flip-flops are not enough.

Step 3 – test $n = 6$: $2^6 = 64$, and $64 \geq 60$, so 6 flip-flops suffice.

Step 4 – conclude: The minimum number of flip-flops is 6.

Final Answer: $n = 6 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – maximum clock frequency of a synchronous register: The clock period must cover the flip-flop propagation delay plus the set-up time, so $f_{max} = \dfrac{1}{t_{pd} + t_{su}}$.

Step 1 – add the two timing terms: $t_{pd} + t_{su} = 6 \text{ ns} + 2 \text{ ns} = 8 \text{ ns}$

Step 2 – convert to seconds: $8 \text{ ns} = 8 \times 10^{-9}$ s

Step 3 – take the reciprocal: $f_{max} = \dfrac{1}{8 \times 10^{-9}}$

Step 4 – evaluate: $f_{max} = 1.25 \times 10^8$ Hz $= 125$ MHz

Final Answer: $f_{max} = 125$ MHz $\Rightarrow \boxed{\text{A}}$

Answer: (A) **Go Back to Q24**

Q25.

Solution

Concept – Laplace transform of a decaying exponential: $\mathcal{L}\{e^{-at}u(t)\} = \dfrac{1}{s+a}$, valid for Re$(s) > -a$.

Step 1 – identify the decay constant: Comparing $e^{-3t}u(t)$ with $e^{-at}u(t)$ gives $a = 3$.

Step 2 – substitute into the standard pair: $X(s) = \dfrac{1}{s+3}$

Step 3 – state the region of convergence: Re$(s) > -3$, which includes the $j\omega$-axis, so the signal has a Fourier transform too.

Why the other options are wrong:

- B, $\dfrac{1}{s-3}$: is the transform of the growing exponential $e^{+3t}u(t)$.
- A and D: are the transforms of a step and a scaled step, not a decaying exponential.

Final Answer: $X(s) = \dfrac{1}{s+3} \Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q25**

Q26.

Solution

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

Step 1 – substitute $s = 0$: $H(0) = \dfrac{20}{0^2 + 6(0) + 8}$

Step 2 – simplify the denominator: $0 + 0 + 8 = 8$

Step 3 – divide: $H(0) = \dfrac{20}{8}$

Step 4 – evaluate: $H(0) = 2.5$

Step 5 – check stability from the plot: The poles are at $s = -2$ and $s = -4$ (both in the left half-plane), so the system is stable and the d.c. gain is meaningful.

Final Answer: $H(0) = 2.5 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – final value theorem: If the system is stable, $x(\infty) = \lim_{s\to 0} sX(s)$.

Step 1 – form $sX(s)$**:** $sX(s) = s \cdot \dfrac{10}{s(s+5)} = \dfrac{10}{s+5}$

Step 2 – check the theorem's validity: The remaining pole is at $s = -5$ (left half-plane), so the final value theorem may be applied.

Step 3 – take the limit $s \to 0$**:** $x(\infty) = \dfrac{10}{0+5}$

Step 4 – evaluate: $x(\infty) = \dfrac{10}{5} = 2$

Final Answer: $x(\infty) = 2 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – Laplace transform of the unit ramp: $\mathcal{L}\{t\,u(t)\} = \dfrac{1}{s^2}$.

Step 1 – start from the step transform: $\mathcal{L}\{u(t)\} = \dfrac{1}{s}$

Step 2 – use the time-multiplication property $\mathcal{L}\{t\,f(t)\} = -\dfrac{d}{ds}F(s)$**:** $\mathcal{L}\{t\,u(t)\} = -\dfrac{d}{ds}\left(\dfrac{1}{s}\right)$

Step 3 – differentiate: $-\dfrac{d}{ds}(s^{-1}) = -(-1)s^{-2} = s^{-2}$

Step 4 – write the result: $\mathcal{L}\{t\,u(t)\} = \dfrac{1}{s^2}$

Final Answer: $\dfrac{1}{s^2} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q28

Q29.

Solution

Concept – length of a linear convolution: If two sequences have lengths L_1 and L_2, their linear convolution has length $L_1 + L_2 - 1$.

Step 1 – list the lengths: $L_1 = 6$, $L_2 = 5$.

Step 2 – add the lengths: $L_1 + L_2 = 6 + 5 = 11$

Step 3 – subtract one: $11 - 1 = 10$

Final Answer: length $= 10 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q29

Q30.

Solution

Concept – Laplace transform of a causal cosine: $\mathcal{L}\{\cos(\omega_0 t)\, u(t)\} = \dfrac{s}{s^2 + \omega_0^2}$.

Step 1 – write the cosine using Euler's identity: $\cos(\omega_0 t) = \dfrac{e^{j\omega_0 t} + e^{-j\omega_0 t}}{2}$

Step 2 – transform each exponential: $\mathcal{L}\{e^{\pm j\omega_0 t} u(t)\} = \dfrac{1}{s \mp j\omega_0}$

Step 3 – average the two transforms: $X(s) = \dfrac{1}{2}\left(\dfrac{1}{s - j\omega_0} + \dfrac{1}{s + j\omega_0}\right)$

Step 4 – combine over a common denominator: $X(s) = \dfrac{1}{2} \cdot \dfrac{(s + j\omega_0) + (s - j\omega_0)}{s^2 + \omega_0^2} = \dfrac{1}{2} \cdot \dfrac{2s}{s^2 + \omega_0^2}$

Step 5 – simplify: $X(s) = \dfrac{s}{s^2 + \omega_0^2}$

Why the other options are wrong:

- A, $\dfrac{\omega_0}{s^2 + \omega_0^2}$: is the transform of $\sin(\omega_0 t) u(t)$.
- D, $\dfrac{s}{s^2 - \omega_0^2}$: is the transform of $\cosh(\omega_0 t) u(t)$.

Final Answer: $X(s) = \dfrac{s}{s^2 + \omega_0^2} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – standard second-order form: Comparing $s^2 + 2\zeta\omega_n s + \omega_n^2$ with the given equation gives ω_n and ζ.

Step 1 – match the constant term: $\omega_n^2 = 25 \Rightarrow \omega_n = 5$ rad/s

Step 2 – match the middle term: $2\zeta\omega_n = 4$

Step 3 – substitute $\omega_n = 5$: $2\zeta(5) = 4$

$10\zeta = 4$

Step 4 – solve for ζ: $\zeta = \dfrac{4}{10} = 0.4$

Step 5 – classify: Since $0 < \zeta < 1$ the system is underdamped, consistent with a pair of complex poles.

Final Answer: $\zeta = 0.4 \Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q31**

Q32.

Solution

Concept – number of root-locus branches: The number of branches of a root locus equals the number of open-loop poles (for $P \geq Z$), since each branch traces one closed-loop pole as K varies.

Step 1 – count the open-loop poles of $\dfrac{K}{s(s+2)(s+4)}$: Poles are at $s = 0$, $s = -2$ and $s = -4$, so $P = 3$.

Step 2 – count the finite zeros: There are no finite zeros, so $Z = 0$.

Step 3 – apply the branch rule: Number of branches $= \max(P, Z) = P = 3$.

Final Answer: 3 branches $\Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q32**

Q33.

Solution

Concept – centroid of the root-locus asymptotes: $\sigma_a = \dfrac{\sum(\text{poles}) - \sum(\text{zeros})}{P - Z}$.

Step 1 – sum the poles: $\sum$ poles $= 0 + (-2) + (-4) = -6$

Step 2 – sum the zeros: $\sum$ zeros $= 0$ (no finite zeros)

Step 3 – form $P - Z$: $P - Z = 3 - 0 = 3$

Step 4 – divide: $\sigma_a = \dfrac{-6-0}{3}$

Step 5 – evaluate: $\sigma_a = -2$

Final Answer: $\sigma_a = -2 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q33

Q34.

Solution

Concept – breakaway point of a root locus: On the real-axis segment the breakaway point is where $\dfrac{dK}{ds} = 0$, using $K = -\dfrac{1}{G(s)H(s)/K}$; here $K = -s(s+3)$.

Step 1 – write K as a function of s: $K = -s(s+3) = -(s^2+3s)$

Step 2 – differentiate with respect to s: $\dfrac{dK}{ds} = -(2s+3)$

Step 3 – set the derivative to zero: $-(2s+3) = 0$

Step 4 – solve for s: $2s+3 = 0 \Rightarrow s = -1.5$

Step 5 – confirm the point lies on the locus: $s = -1.5$ is between the poles 0 and -3, which is a valid real-axis locus segment, so it is the breakaway point.

Final Answer: breakaway at $s = -1.5 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

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

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

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

Step 3 – take the reciprocal for the error: $e_{ss} = \dfrac{1}{K_v} = \dfrac{1}{4}$

Step 4 – evaluate: $e_{ss} = 0.25$

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

Answer: (B) Go Back to Q35

Q36.

Solution

Concept – amplitude-shift keying: In ASK (on–off keying in its simplest form) the carrier amplitude is switched between two levels according to the binary data, while the carrier frequency and phase stay fixed.

Step 1 – read the waveform: The carrier is present at full amplitude during the two "1" bits and vanishes during the "0" bit; only the amplitude changes.

Step 2 – match to the keying definitions: Amplitude switched, frequency and phase unchanged $\Rightarrow$ amplitude-shift keying.

Why the other options are wrong:

- A, FSK: would change the carrier **frequency** between bits, not its amplitude.
- C, PSK: would change the carrier **phase**, keeping the amplitude constant.
- D, QAM: varies amplitude **and** phase together to carry several bits per symbol.

Final Answer: amplitude-shift keying (ASK) $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – Carson's rule for FM bandwidth: $B = 2(\Delta f + f_m)$, the sum of the peak deviation and the modulating frequency, doubled.

Step 1 – list the data: $\Delta f = 75$ kHz, $f_m = 15$ kHz.

Step 2 – add the deviation and the modulating frequency: $\Delta f + f_m = 75 + 15 = 90$ kHz

Step 3 – multiply by two: $B = 2 \times 90$

Step 4 – evaluate: $B = 180$ kHz

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

Answer: (A) Go Back to Q37

Q38.

Solution

Concept – PCM bit rate: $R_b = f_s \times n$, where $n = \log_2 L$ bits encode L quantization levels sampled at f_s.

Step 1 – find the number of bits per sample: $n = \log_2(64) = \log_2(2^6) = 6$ bits

Step 2 – list the sampling rate: $f_s = 10$ kHz $= 10000$ samples/s

Step 3 – multiply: $R_b = 6 \times 10000$

Step 4 – evaluate: $R_b = 60000$ bps $= 60$ kbps

Final Answer: $R_b = 60$ kbps $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – bits per symbol of an M-ary scheme: Each symbol carries $\log_2 M$ bits, where M is the number of constellation points.

Step 1 – count the constellation points: The 8-PSK constellation shows $M = 8$ equally spaced points.

Step 2 – take the base-2 logarithm: $\log_2(8) = \log_2(2^3) = 3$

Step 3 – state the result: 3 bits are carried per transmitted symbol.

Why the other options are wrong:

- A, 8: is the number of symbols M, not the bits per symbol.
- C, 2: would be QPSK ($M = 4$).
- B, 1: would be BPSK ($M = 2$).

Final Answer: 3 bits/symbol $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – entropy of a discrete source: $H = \sum_i p_i \log_2 \dfrac{1}{p_i}$ bits/symbol.

Step 1 – write the term for each symbol: $p_1 = \frac{1}{2} : \frac{1}{2}\log_2 2 = \frac{1}{2} \times 1 = 0.5$

$p_2 = \frac{1}{4} : \frac{1}{4}\log_2 4 = \frac{1}{4} \times 2 = 0.5$

$p_3 = \frac{1}{8} : \frac{1}{8}\log_2 8 = \frac{1}{8} \times 3 = 0.375$

$p_4 = \frac{1}{8} : \frac{1}{8}\log_2 8 = \frac{1}{8} \times 3 = 0.375$

Step 2 – add the four contributions: $H = 0.5 + 0.5 + 0.375 + 0.375$

Step 3 – evaluate: $H = 1.75$ bits/symbol

Step 4 – note: This is below the $\log_2 4 = 2$ bits/symbol of a uniform source, because the unequal probabilities carry less average information.

Final Answer: $H = 1.75$ bits/symbol $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q40

Q41.

Solution

Concept – Shannon–Hartley channel capacity: $C = B\log_2(1 + \text{SNR})$.

Step 1 – form the term inside the logarithm: $1 + \text{SNR} = 1 + 15 = 16$

Step 2 – take the base-2 logarithm: $\log_2(16) = \log_2(2^4) = 4$

Step 3 – multiply by the bandwidth: $C = 4000 \times 4$

Step 4 – evaluate: $C = 16000$ bps $= 16$ kbps

Final Answer: $C = 16$ kbps $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – characteristic impedance of a lossless line: $Z_0 = \sqrt{\frac{L}{C}}$, with L and C the per-unit-length inductance and capacitance.

Step 1 – convert the values to base units: $L = 225$ nH/m $= 225 \times 10^{-9}$ H/m

$C = 40$ pF/m $= 40 \times 10^{-12}$ F/m

Step 2 – form the ratio L/C: $\frac{L}{C} = \frac{225 \times 10^{-9}}{40 \times 10^{-12}}$

Step 3 – simplify: $= \frac{225}{40} \times 10^3 = 5.625 \times 10^3 = 5625$

Step 4 – take the square root: $Z_0 = \sqrt{5625}$

$Z_0 = 75\ \Omega$

Final Answer: $Z_0 = 75\ \Omega \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – reflection coefficient and VSWR: $\Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0}$ and VSWR $= \dfrac{1+|\Gamma|}{1-|\Gamma|}$.

Step 1 – compute the numerator of Γ: $Z_L - Z_0 = 25 - 75 = -50$

Step 2 – compute the denominator of Γ: $Z_L + Z_0 = 25 + 75 = 100$

Step 3 – form Γ and take its magnitude: $\Gamma = \dfrac{-50}{100} = -0.5 \Rightarrow |\Gamma| = 0.5$

Step 4 – form the VSWR numerator and denominator: $1 + |\Gamma| = 1 + 0.5 = 1.5$

$1 - |\Gamma| = 1 - 0.5 = 0.5$

Step 5 – divide: $\text{VSWR} = \dfrac{1.5}{0.5}$

$\text{VSWR} = 3$

Final Answer: $\text{VSWR} = 3 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q43

Q44.

Solution

Concept – reflection coefficient from VSWR: Inverting $\text{VSWR} = \dfrac{1+|\Gamma|}{1-|\Gamma|}$ gives $|\Gamma| = \dfrac{\text{VSWR}-1}{\text{VSWR}+1}$.

Step 1 – compute the numerator: $\text{VSWR} - 1 = 2 - 1 = 1$

Step 2 – compute the denominator: $\text{VSWR} + 1 = 2 + 1 = 3$

Step 3 – form the ratio: $|\Gamma| = \dfrac{1}{3}$

Step 4 – evaluate: $|\Gamma| = 0.333$

Final Answer: $|\Gamma| = 0.333 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – wavelength of a plane wave: $\lambda = \dfrac{c}{f}$, with c the speed of light.

Step 1 – list the data: $c = 3 \times 10^8$ m/s, $f = 1.5$ GHz $= 1.5 \times 10^9$ Hz.

Step 2 – divide: $\lambda = \dfrac{3 \times 10^8}{1.5 \times 10^9}$

Step 3 – simplify the powers of ten: $\lambda = 2 \times 10^{-1}$ m

Step 4 – convert to centimetres: $\lambda = 0.2$ m $= 20$ cm

Final Answer: $\lambda = 20 \text{ cm} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q45

Q46.

Solution

Concept – quarter-wave impedance transformer: A $\lambda/4$ section of characteristic impedance Z_0' transforms a load Z_L to $Z_{in} = \dfrac{(Z_0')^2}{Z_L}$; matching Z_{in} to the line requires $Z_0' = \sqrt{Z_{line} Z_L}$.

Step 1 – list the data: $Z_{line} = 100\ \Omega$, $Z_L = 50\ \Omega$.

Step 2 – form the product: $Z_{line} Z_L = 100 \times 50 = 5000$

Step 3 – take the square root: $Z_0' = \sqrt{5000}$

Step 4 – evaluate: $Z_0' = 70.71\ \Omega \approx 70.7\ \Omega$

Why the other options are wrong:

- A, $50\ \Omega$ and D, $100\ \Omega$: are the two impedances being matched, not the geometric mean.
- B, $150\ \Omega$: is their sum, which has no matching significance.

Final Answer: $Z_0' \approx 70.7\ \Omega \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q46

Answer Key

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