Nepal Engineering Council (NEC)
Computer Engineering
Software Engineering
Information and Technology Engineering
Electronics, Communication and Information
Electronics, ETC & ITTC Engineering (Code: AExE)

Chapter 1: Concept of Basic Electrical and Electronics Engineering

COMPLETE NOTES WITH SOLVED MCQ AND PYQS

EASY EXPLANATION



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Chapter 1: Concept of Basic Electrical and Electronics Engineering

This chapter lays the foundation for the whole AExE syllabus: basic circuit laws, network theorems, AC fundamentals, semiconductor devices, oscillators and amplifiers. These concepts recur throughout Chapters 2–9, so a solid grasp here pays off across the entire exam.

1.1 Basic Concept

1.1.1 Ohm's Law and Basic Electrical Quantities

- Ohm's Law: V = IR — the current through a conductor is directly proportional to the voltage across it, provided physical conditions (chiefly temperature) remain constant; equivalently I = V/R and R = V/I.
- Ohm's law does NOT apply to non-linear elements such as diodes and transistors, whose resistance is not constant but depends on the operating voltage/current.
- Electric charge Q (coulombs) is the fundamental quantity; current I = dQ/dt is the rate of flow of charge (amperes); voltage V is the work done per unit charge moving between two points (volts).
- Power P = VI = I^2R = V^2/R (watts) is the rate of doing electrical work; Energy E = P×t (joules), with the commercial/billing unit being the kilowatt-hour (kWh, 1 unit of electricity = 1 kW drawn for 1 hour).

1.1.2 Conducting and Insulating Materials

- Conductors have very low resistivity (≈ 10^{-8} Ω·m), e.g. copper, aluminium, silver — abundant free (valence) electrons allow easy current flow.
- Insulators have very high resistivity (≈ 10^{10}–10^{14} Ω·m), e.g. mica, glass, rubber — negligible free electrons, current flow is practically blocked.
- Semiconductors (e.g. silicon, germanium) lie between the two, with resistivity/conductivity that can be precisely controlled via doping, temperature or an applied field — the basis of all solid-state devices covered in Section 1.4.

1.1.3 Series and Parallel Circuits

- Series circuit: elements connected end-to-end so the same current I flows through every element; the source voltage divides across the elements: V = V_1+V_2+V_3, and Req = R_1+R_2+R_3+...
- Parallel circuit: elements connected across the same two nodes so the same voltage V appears across every element; the source current divides among the branches: I = I_1+I_2+I_3, and 1/Req = 1/R_1+1/R_2+1/R_3+...

1.1.4 Star–Delta (Y–Δ) Conversion

- A 3-terminal resistive network can be represented either as a star (Y, three resistors meeting at a common neutral point) or a delta (Δ, three resistors forming a triangle) — the two are electrically equivalent at the terminals if converted using the correct formulas, which is often used to simplify bridge-type networks that are neither purely series nor purely parallel.
- Delta-to-Star: R_A = (R_ab·R_ca)/(R_ab+R_bc+R_ca), and similarly for R_B, R_C (cyclic permutation).
- Star-to-Delta: R_ab = (R_A·R_B + R_B·R_C + R_C·R_A)/R_C, and similarly for the others — the numerator (sum of all pairwise products of the star resistances) is the same in every formula; only the denominator (the star resistor opposite the delta side being found) changes.

1.1.5 Kirchhoff's Laws

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- Kirchhoff's Current Law (KCL): the algebraic sum of currents at any node is zero ($\Sigma I_{in} = \Sigma I_{out}$) — a direct consequence of conservation of charge, since charge cannot accumulate at an ideal node.
- Kirchhoff's Voltage Law (KVL): the algebraic sum of voltage drops and rises around any closed loop is zero — a direct consequence of conservation of energy, since a charge returning to its starting point must have zero net potential change.

1.1.6 Classification of Circuits and Elements

- Linear circuit/element: obeys Ohm's law; parameters (R, L, C) are independent of the applied voltage or current (e.g., an ideal resistor).
- Non-linear circuit/element: the voltage-current relationship is not a straight line through the origin (e.g., a diode, transistor).
- Bilateral element: behaves identically for current flowing in either direction (e.g., a resistor).
- Unilateral element: behaviour changes depending on the direction of current flow (e.g., a diode conducts one way only).
- Active element: capable of delivering energy or providing power gain to a circuit (e.g., a battery, transistor, op-amp).
- Passive element: can only store or dissipate energy, never generate net power (e.g., resistor, inductor, capacitor).

Quantity	Formula / Relation	SI Unit
Ohm's Law	$V = IR$	Volt (V)
Power	$P = VI = I^2R = V^2/R$	Watt (W)
Energy	$E = P \times t$	Joule (J); commercial unit kWh
Series resistance	$R_{eq} = R_1+R_2+R_3+...$	Ohm (Ω)
Parallel resistance	$1/R_{eq} = 1/R_1+1/R_2+1/R_3+...$	Ohm (Ω)
Delta→Star	$R_A = (R_{ab} \cdot R_{ca})/(R_{ab}+R_{bc}+R_{ca})$	Ohm (Ω)
Star→Delta	$R_{ab} = (R_A R_B+R_B R_C+R_C R_A)/R_C$	Ohm (Ω)

Table 1.1: Key formulas for basic electrical quantities and circuit conversions.

Classification	Property	Example
Linear / Non-linear	Constant R,L,C vs. voltage-dependent	Resistor (linear) / Diode (non-linear)
Bilateral / Unilateral	Same behaviour both directions vs. direction-dependent	Resistor (bilateral) / Diode (unilateral)
Active / Passive	Can supply net energy/gain vs. only stores/dissipates	Transistor (active) / Resistor, L, C (passive)

Table 1.2: Classification of circuit elements.

Quick-Solve Case	Shortcut Formula	Worked Example
N equal resistors R in series	$R_{eq} = N \times R$	$3 \times 10\Omega$ in series = 30Ω
N equal resistors R in parallel	$R_{eq} = R / N$	$3 \times 10\Omega$ in parallel = 3.33Ω
Two resistors in parallel	$R_{eq} = (R_1 \times R_2)/(R_1+R_2)$	$6\Omega \parallel 3\Omega = 2\Omega$

Quick-Solve Case	Shortcut Formula	Worked Example
Voltage divider (series R_1,R_2)	$V_{R2} = V_{in} \times R_2/(R_1+R_2)$	10V across 2Ω+3Ω: V_{R2} = 6V
Delta of 3 equal resistors R → Star	$R_Y = R/3$ (each arm)	Δ of 30Ω → Y of 10Ω each
Energy billing	Units (kWh) = kW × hours	2kW heater, 3h = 6 units

Table 1.3: Quick-solve shortcuts commonly needed for Section 1.1 numerical MCQs.

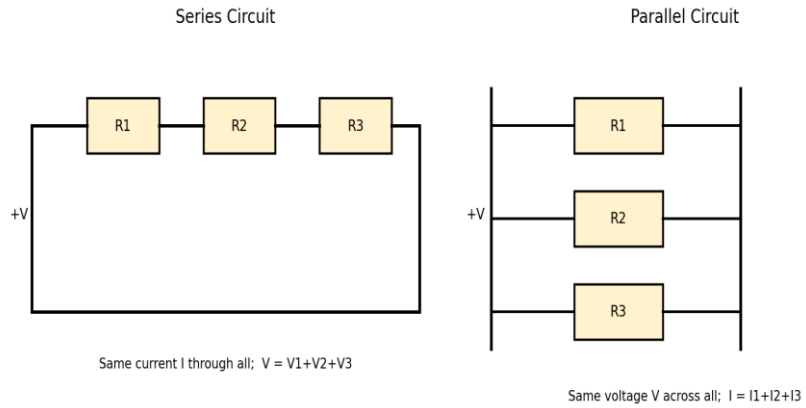


Fig. 1.1: Series circuit (same current, voltages add) versus parallel circuit (same voltage, currents add).

Solved MCQs

Q1. Ohm's law is valid provided that:

(A) Resistance varies with current

(B) Temperature remains constant

(C) The circuit is non-linear

(D) Only AC is applied

Answer: (B) Temperature remains constant

Explanation: *Ohm's law V=IR holds only when the resistance stays constant, which in practice requires temperature (and other physical conditions) to remain constant; non-linear elements like diodes do not obey it.*

Q2. In a purely series circuit, which quantity remains the same through every element?

(A) Voltage

(B) Power

(C) Current

(D) Resistance

Answer: (C) Current

Explanation: *Series-connected elements share a single conduction path, so the same current flows through each one, while the applied voltage divides among them.*

Q3. Kirchhoff's Current Law (KCL) is a direct consequence of the conservation of:

(A) Energy

(B) Charge

(C) Momentum

(D) Mass only

Answer: (B) Charge

Explanation: *KCL states that the total current entering a node equals the total current leaving it, which follows directly from the principle that electric charge cannot accumulate at an ideal node (conservation of charge).*

Q4. A diode is best classified as a:

(A) Linear, bilateral element

(B) Non-linear, unilateral element

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(C) Linear, unilateral element

(D) Non-linear, bilateral element

Answer: (B) Non-linear, unilateral element

Explanation: *A diode's V-I curve is not a straight line (non-linear) and it conducts current mainly in one direction only (unilateral), unlike a resistor which is both linear and bilateral.*

Q5. A 12V battery is connected across a 4Ω resistor. The current drawn is:

(A) 2A

(B) 3A

(C) 4A

(D) 48A

Answer: (B) 3A

Explanation: *By Ohm's law, $I = V/R = 12/4 = 3A$.*

Q6. Three resistors of 2Ω, 3Ω and 5Ω are connected in series. The equivalent resistance is:

(A) 10Ω

(B) 0.97Ω

(C) 5Ω

(D) 30Ω

Answer: (A) 10Ω

Explanation: *In series, resistances simply add: $R_{eq} = 2+3+5 = 10\Omega$.*

Q7. Two resistors of 6Ω and 3Ω are connected in parallel. The equivalent resistance is:

(A) 9Ω

(B) 2Ω

(C) 4.5Ω

(D) 18Ω

Answer: (B) 2Ω

Explanation: *For two resistors in parallel, $R_{eq} = (R_1R_2)/(R_1+R_2) = (6\times3)/(6+3) = 18/9 = 2\Omega$.*

Q8. A device consumes 2kW of power for 3 hours. The electrical energy consumed, in commercial units (kWh), is:

(A) 2 units

(B) 3 units

(C) 6 units

(D) 600 units

Answer: (C) 6 units

Explanation: *Energy = Power × Time = 2kW × 3h = 6 kWh, i.e., 6 commercial units.*

Q9. A resistor carries a current of 5A and dissipates 500W. Its resistance is:

(A) 100Ω

(B) 25Ω

(C) 20Ω

(D) 2.5Ω

Answer: (C) 20Ω

Explanation: *$P = I^2R \Rightarrow R = P/I^2 = 500/25 = 20\Omega$.*

Q10. At a circuit node, currents of 5A and 3A flow in, and a single current I flows out. By KCL, I equals:

(A) 2A

(B) 8A

(C) 15A

(D) 0A

Answer: (B) 8A

Explanation: *KCL requires $\Sigma I_{in} = \Sigma I_{out}$, so $I = 5+3 = 8A$.*

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Q11. A delta network has three equal arms of 30Ω each. The equivalent star network has each arm equal to:

(A) 30Ω
(B) 90Ω
(C) 10Ω
(D) 15Ω

Answer: (C) 10Ω

Explanation: *For a symmetric delta of equal resistance R, the equivalent star resistance per arm is R/3 = 30/3 = 10Ω.*

Q12. Which of the following is the correct order of resistivity, from lowest to highest?

(A) Insulator < Semiconductor < Conductor
(B) Conductor < Semiconductor < Insulator
(C) Semiconductor < Conductor < Insulator
(D) Conductor < Insulator < Semiconductor

Answer: (B) Conductor < Semiconductor < Insulator

Explanation: *Conductors have the lowest resistivity (≈10^{-8} Ω·m), semiconductors are intermediate, and insulators have the highest resistivity (≈10^{10}–10^{14} Ω·m).*

Q13. Silicon and germanium are examples of:

(A) Conductors
(B) Insulators
(C) Semiconductors
(D) Superconductors

Answer: (C) Semiconductors

Explanation: *Silicon and germanium are the two most common semiconductor materials, with resistivity/conductivity controllable via doping and temperature.*

Q14. An inductor is classified as a:

(A) Active element
(B) Passive element
(C) Non-linear element only
(D) Unilateral element only

Answer: (B) Passive element

Explanation: *An inductor can only store energy in its magnetic field and dissipate none (ideally); it cannot generate net power, so it is a passive element.*

Q15. In a parallel circuit of three branches carrying 2A, 3A and 4A, the total current drawn from the source is:

(A) 4A
(B) 9A
(C) 24A
(D) 1.5A

Answer: (B) 9A

Explanation: *In a parallel circuit, branch currents add: I_total = 2+3+4 = 9A.*

Q16. Two equal resistors R are first connected in series and then in parallel. The ratio of series to parallel equivalent resistance is:

(A) 1:1
(B) 2:1
(C) 4:1
(D) 1:4

Answer: (C) 4:1

Explanation: *Series equivalent = 2R; parallel equivalent = R/2. Ratio = 2R/(R/2) = 4:1.*

Q17. A voltage divider has R_1=2Ω and R_2=3Ω in series across a 10V supply. The voltage across R_2 is:

(A) 4V

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(B) 6V
(C) 10V
(D) 2V

Answer: (B) 6V

Explanation: *$V_R2 = V_in \times R_2/(R_1+R_2) = 10 \times 3/5 = 6V$.*

Q18. Kirchhoff's Voltage Law (KVL) is based on the conservation of:

(A) Charge
(B) Energy
(C) Current
(D) Mass

Answer: (B) Energy

Explanation: *KVL states that the algebraic sum of voltage drops/rises around a closed loop is zero, which follows from conservation of energy (a charge returning to its start has zero net energy change).*

Q19. A battery supplying current to a circuit is an example of a/an:

(A) Passive element
(B) Active element
(C) Unilateral element only
(D) Bilateral element only

Answer: (B) Active element

Explanation: *A battery can deliver (generate) electrical energy to a circuit, which is the defining property of an active element.*

Q20. The commercial unit of electrical energy, 1 kWh, is equivalent to a power of:

(A) 1 Watt used for 1 second
(B) 1 kilowatt used for 1 hour
(C) 1 Watt used for 1 hour
(D) 1 Megawatt used for 1 second

Answer: (B) 1 kilowatt used for 1 hour

Explanation: *1 unit of electricity (kWh) is defined as 1 kilowatt of power consumed continuously for 1 hour: $E = P \times t = 1kW \times 1h = 1kWh$.*

Q21. A resistor is an example of an element that is:

(A) Non-linear and unilateral
(B) Linear and bilateral
(C) Active and non-linear
(D) Linear and unilateral

Answer: (B) Linear and bilateral

Explanation: *An ideal resistor obeys Ohm's law (linear, constant R) and behaves identically regardless of current direction (bilateral).*

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1.2 Network Theorems

1.2.1 Superposition Theorem

- In any linear network containing multiple independent sources, the response (voltage or current) in any element equals the algebraic sum of the responses caused by each source acting alone, with every other source deactivated.
- Deactivating a source: an ideal voltage source is replaced by a short circuit (set to 0 V); an ideal current source is replaced by an open circuit (set to 0 A). Analyse the circuit once per source, then add all the individual contributions (respecting sign/direction) to get the total response.

1.2.2 Thevenin's and Norton's Theorems

- Thevenin's Theorem: any linear two-terminal network, however complex, can be reduced to a single equivalent voltage source V_{th} in series with a single equivalent resistance R_{th}, as seen from the two terminals of interest.
- Norton's Theorem: the same network can equally be reduced to a single equivalent current source I_N in parallel with a resistance R_N — Thevenin and Norton equivalents of the same network are related by simple source transformation.
- Relations: $R_{th} = R_N$; $I_N = V_{th}/R_{th}$; $V_{th} = I_N \times R_N$. R_{th} (or R_N) is found by deactivating all independent sources and calculating the resistance seen looking into the open-circuited terminals.

1.2.3 Maximum Power Transfer Theorem

- For a DC source with fixed Thevenin resistance R_{th} supplying a variable load R_L, maximum power is delivered to the load when $R_L = R_{th}$ — at this matched condition, the power transfer efficiency is only 50% (half the total power is dissipated inside the source's own R_{th}).
- Maximum power delivered: $P_{max} = V_{th}^2/(4R_{th})$.

1.2.4 R-L, R-C and R-L-C Circuits, Resonance

- Inductive reactance $X_L = \omega L = 2\pi fL$ (Ω) — in a purely inductive circuit, current lags voltage by 90°.
- Capacitive reactance $X_C = 1/\omega C = 1/(2\pi fC)$ (Ω) — in a purely capacitive circuit, current leads voltage by 90°.
- Impedance of a series R-L-C circuit: $Z = R + j(X_L - X_C)$, with magnitude $|Z| = \sqrt{(R^2+(X_L-X_C)^2)}$.
- Series resonance occurs when $X_L = X_C$, at which the reactive parts cancel, impedance is purely resistive and minimum ($|Z|=R$), and current is maximum for a given applied voltage.
- Parallel resonance (of a practical tank circuit) instead gives maximum impedance and minimum line current drawn from the source, the opposite behaviour to series resonance.
- Resonant frequency: $f_0 = 1/(2\pi\sqrt{(LC)})$ — the same formula applies to both series and parallel L-C combinations.

1.2.5 Active and Reactive Power

- Active (real) power $P = VI\cos\varphi$ (Watts) — the power that actually does useful work (e.g., heat, mechanical work).
- Reactive power $Q = VI\sin\varphi$ (VAR) — power that oscillates between source and reactive elements (L, C) without being consumed.
- Apparent power $S = VI$ (VA), with $S^2 = P^2+Q^2$; the power factor $\cos\varphi = P/S$ is the fraction of apparent power that performs real work — utilities penalise a low power factor because it means more current (and I^2R loss) is needed to deliver the same real power.

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Theorem	Statement (Key Idea)	Typical Use
Superposition	Total response = sum of responses to each source acting alone (others deactivated)	Multi-source linear circuit analysis
Thevenin's	Reduce 2-terminal network to V_th in series with R_th	Simplifying a complex network to analyse one load
Norton's	Reduce 2-terminal network to I_N in parallel with R_N	Alternative to Thevenin; convenient for parallel loads
Maximum Power Transfer	Max power delivered to load when R_L = R_th (DC case)	Impedance matching, amplifier/antenna design

Table 1.3: Summary of key network theorems.

Quantity	Formula	Unit
Inductive reactance	$X_L = 2\pi fL$	Ohm (Ω)
Capacitive reactance	$X_C = 1/(2\pi fC)$	Ohm (Ω)
Resonant frequency	$f_0 = 1/(2\pi\sqrt{(LC)})$	Hertz (Hz)
Active power	$P = VI\cos\varphi$	Watt (W)
Reactive power	$Q = VI\sin\varphi$	VAR
Apparent power	$S = VI$; $S^2 = P^2+Q^2$	VA

Table 1.4: AC circuit and power formulas.

Quick-Solve Case	Shortcut Formula	Worked Example
Norton from Thevenin	$I_N = V_{th}/R_{th}$, $R_N = R_{th}$	V_{th}=10V, R_{th}=5Ω → I_N=2A
Max power (DC)	$P_{max} = V_{th}^2/(4R_{th})$	V_{th}=20V, R_{th}=5Ω → P_{max}=20W
Series RLC impedance	$\lvert Z\rvert = \sqrt{(R^2+(X_L-X_C)^2)}$	R=3, X_L=8, X_C=4 → $\lvert Z\rvert$=5Ω
Power triangle	$S^2 = P^2 + Q^2$	P=80W, Q=60VAR → S=100VA
Power factor	$\cos\varphi = P/S$	P=80W, S=100VA → pf=0.8
Resonant frequency	$f_0 = 1/(2\pi\sqrt{(LC)})$	L=1H, C=1μF → f_0≈159Hz

Table 1.5: Quick-solve shortcuts for Section 1.2 numerical MCQs.

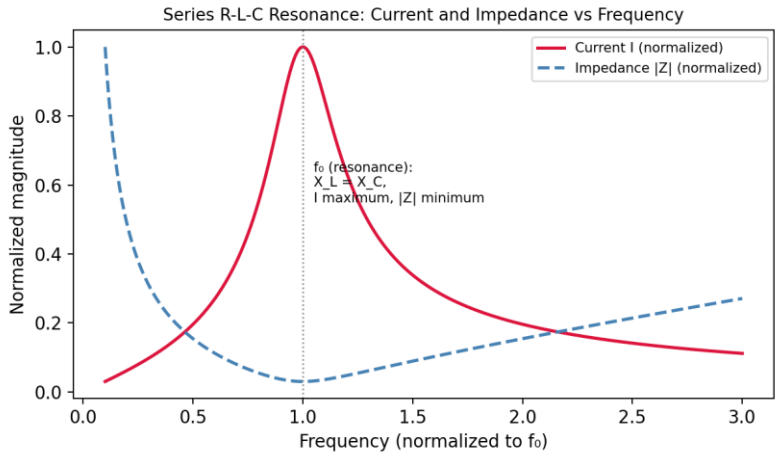


Fig. 1.2: Series R-L-C resonance — current peaks and impedance is minimum exactly at the resonant frequency f_0, where $X_L = X_C$.

Solved MCQs

Q22. While applying the superposition theorem, an ideal voltage source is replaced by:

(A) Open circuit
(B) Short circuit
(C) Another voltage source
(D) Current source

Answer: (B) Short circuit

Explanation: *Deactivating an ideal voltage source means setting its value to 0 V, which is electrically equivalent to a short circuit across its terminals.*

Q23. Thevenin's equivalent circuit consists of:

(A) A current source in parallel with a resistance
(B) A voltage source in series with a resistance
(C) Two voltage sources
(D) Only a resistance

Answer: (B) A voltage source in series with a resistance

Explanation: *Thevenin's theorem reduces any linear two-terminal network to a single voltage source V_{th} in series with a single resistance R_{th}.*

Q24. Maximum power is transferred to a DC load when the load resistance equals:

(A) Zero
(B) Infinity
(C) The Thevenin resistance of the source network
(D) Twice the source resistance

Answer: (C) The Thevenin resistance of the source network

Explanation: *The maximum power transfer theorem states that for a fixed source, maximum power is delivered to the load when $R_L = R_{th}$, at which point the transfer efficiency is exactly 50%.*

Q25. At series resonance, the circuit impedance is:

(A) Maximum
(B) Minimum and equal to R
(C) Equal to X_L only
(D) Infinite

Answer: (B) Minimum and equal to R

Explanation: *At series resonance $X_L = X_C$, so the reactive terms cancel exactly, leaving the impedance purely resistive and at its minimum value, $Z=R$, which is why current is maximum at resonance.*

Q26. A network has Thevenin voltage 10V and Thevenin resistance 5Ω. Its Norton equivalent current source I_N is:

(A) 50A
(B) 2A
(C) 0.5A
(D) 15A

Answer: (B) 2A

Explanation: *$I_N = V_{th}/R_{th} = 10/5 = 2A$, with Norton resistance $R_N = R_{th} = 5\Omega$.*

Q27. A source has $V_{th} = 20V$ and $R_{th} = 5\Omega$. The maximum power that can be delivered to a matched load is:

(A) 20W
(B) 40W
(C) 80W

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(D) 100W

Answer: (A) 20W

Explanation: *$P_{max} = V_{th}^2/(4R_{th}) = 20^2/(4\times5) = 400/20 = 20W$.*

Q28. In a series R-L-C circuit, R=3Ω, X_L=8Ω and X_C=4Ω. The magnitude of impedance is:

(A) 5Ω

(B) 7Ω

(C) 11Ω

(D) 3Ω

Answer: (A) 5Ω

Explanation: *$|Z| = \sqrt{(R^2+(X_L-X_C)^2)} = \sqrt{(3^2+4^2)} = \sqrt{(9+16)} = \sqrt{25} = 5\Omega$.*

Q29. A circuit has active power 80W and apparent power 100VA. Its power factor is:

(A) 1.25

(B) 0.8

(C) 8.0

(D) 0.08

Answer: (B) 0.8

Explanation: *Power factor $\cos\varphi = P/S = 80/100 = 0.8$.*

Q30. A load has active power 80W and reactive power 60VAR. Its apparent power is:

(A) 140VA

(B) 20VA

(C) 100VA

(D) 4800VA

Answer: (C) 100VA

Explanation: *$S = \sqrt{(P^2+Q^2)} = \sqrt{(80^2+60^2)} = \sqrt{(6400+3600)} = \sqrt{10000} = 100VA$.*

Q31. A series circuit has L = 1H and C = 1μF. Its resonant frequency is approximately:

(A) 15.9 Hz

(B) 159 Hz

(C) 1.59 kHz

(D) 15.9 kHz

Answer: (B) 159 Hz

Explanation: *$f_0 = 1/(2\pi\sqrt{(LC)}) = 1/(2\pi\sqrt{(1\times10^{-6})}) = 1/(2\pi\times0.001) \approx 159$ Hz.*

Q32. In a purely inductive AC circuit, the current:

(A) Leads the voltage by 90°

(B) Lags the voltage by 90°

(C) Is in phase with voltage

(D) Leads the voltage by 180°

Answer: (B) Lags the voltage by 90°

Explanation: *In a purely inductive circuit, current lags the applied voltage by exactly 90° (a quarter cycle).*

Q33. In a purely capacitive AC circuit, the current:

(A) Leads the voltage by 90°

(B) Lags the voltage by 90°

(C) Is in phase with voltage

(D) Lags the voltage by 180°

Answer: (A) Leads the voltage by 90°

Explanation: *In a purely capacitive circuit, current leads the applied voltage by exactly 90°.*

Q34. At parallel resonance, the impedance of the tank circuit and the line current from the source are respectively:

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(A) Minimum, maximum
(B) Maximum, minimum
(C) Both maximum
(D) Both minimum

Answer: (B) Maximum, minimum

Explanation: *Parallel resonance is the opposite of series resonance: circuit impedance is maximum, so the current drawn from the source is minimum.*

Q35. To find R_th of a network for Thevenin's theorem, all independent sources are:

(A) Left unchanged
(B) Deactivated (voltage sources shorted, current sources opened)
(C) Doubled in value
(D) Replaced by a single resistor of value 1Ω

Answer: (B) Deactivated (voltage sources shorted, current sources opened)

Explanation: *R_th is found by deactivating every independent source (short-circuiting voltage sources, open-circuiting current sources) and computing the resistance seen from the open terminals.*

Q36. A pure resistor carrying AC has active power P and reactive power Q. For this resistor, Q equals:

(A) P
(B) 0
(C) S
(D) Infinite

Answer: (B) 0

Explanation: *A pure resistor has $\varphi=0°$, so $Q = VI\sin\varphi = 0$; all the apparent power is active (real) power.*

Q37. The efficiency of power transfer at the maximum power transfer condition (R_L=R_th, DC case) is:

(A) 100%
(B) 75%
(C) 50%
(D) 25%

Answer: (C) 50%

Explanation: *At R_L=R_th, equal power is dissipated in the source resistance and the load, so only half the total generated power reaches the load — an efficiency of exactly 50%.*

Q38. A low power factor in an AC system mainly causes:

(A) Reduced current for the same real power
(B) Increased current (and I^2R losses) for the same real power
(C) No effect on system performance
(D) Increased voltage only

Answer: (B) Increased current (and I^2R losses) for the same real power

Explanation: *For a fixed real power P, a lower power factor ($\cos\varphi$) means the current $I = P/(V\cos\varphi)$ must be higher, increasing I^2R losses in the supply system — this is why utilities penalise poor power factor.*

Q39. Norton's theorem reduces a linear two-terminal network to:

(A) A voltage source in series with a resistance
(B) A current source in parallel with a resistance
(C) Two current sources in series
(D) A single capacitor

Answer: (B) A current source in parallel with a resistance

Explanation: *Norton's theorem represents any linear two-terminal network as an equivalent current source I_N in parallel with a resistance R_N.*

Q40. The superposition theorem can be validly applied only to circuits that are:

(A) Purely resistive
(B) Linear (containing only linear elements)

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(C) Non-linear

(D) Containing only one source

Answer: (B) Linear (containing only linear elements)

Explanation: *Superposition is a property of linear systems only; it cannot be validly applied to networks containing non-linear elements such as diodes or transistors.*

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1.3 Alternating Current Fundamentals

1.3.1 Generation of Alternating EMF

- An alternating EMF is generated by rotating a coil at constant angular velocity within a uniform magnetic field (Faraday's law of electromagnetic induction) — the induced EMF varies sinusoidally as the angle between the coil and field changes.
- Instantaneous EMF: $e = E_m \sin(\omega t)$, where E_m is the peak (maximum) value and $\omega = 2\pi f$ is the angular frequency (rad/s), f being the frequency in Hz.

1.3.2 Important AC Values

- Average value (over a half cycle, since the full-cycle average of a symmetric sinusoid is zero): $E_{avg} = 0.637 \times E_m$.
- RMS (root-mean-square) value: $E_{rms} = 0.707 \times E_m$ — physically, this is the 'effective' or DC-equivalent value that would produce the same heating effect in a resistor as the AC waveform; virtually all AC meters are calibrated to read RMS values.
- Form Factor = RMS/Average = $0.707/0.637 \approx 1.11$ for a pure sine wave — a measure of the waveform's shape (how peaked or flat it is).
- Peak (Crest) Factor = Peak/RMS = $1/0.707 \approx 1.414$ — indicates how much higher the peak is compared to the effective (RMS) value; important for rating equipment against voltage spikes.

1.3.3 Three-Phase System

- A three-phase supply consists of three sinusoidal voltages of the same magnitude and frequency, mutually displaced by 120° in phase — used almost universally for bulk power generation, transmission and distribution because it is more efficient (less conductor material for the same power) than single-phase supply and gives smoother, near-constant instantaneous power to three-phase loads (e.g., motors).
- Star (Y) connection: all three phase windings' one end joined at a common neutral point N; the line voltage exceeds the phase voltage by √3: $V_L = \sqrt{3} \times V_{ph}$, while the line current equals the phase current: $I_L = I_{ph}$.
- Delta (Δ) connection: the three phase windings are connected end-to-end forming a closed triangle (loop), with each corner brought out as a line terminal; here the line voltage equals the phase voltage: $V_L = V_{ph}$, while the line current exceeds the phase current by √3: $I_L = \sqrt{3} \times I_{ph}$.
- In a perfectly balanced three-phase system (equal loads on all three phases), the neutral current in a star connection is zero, since the three phase currents (equal magnitude, 120° apart) sum to zero.

AC Parameter	Formula (relative to E_m)	Approx. Value
Average value (half cycle)	$0.637 \times E_m$	63.7% of peak
RMS value	$0.707 \times E_m$	70.7% of peak
Form factor	RMS / Average	≈ 1.11
Peak (crest) factor	Peak / RMS	≈ 1.414

Table 1.5: Key AC waveform parameters for a pure sinusoid.

Connection	Line Voltage (V_L)	Line Current (I_L)	Typical Use
Star (Y)	$\sqrt{3} \times V_{ph}$	I_{ph}	Distribution systems (neutral available for single-phase loads)

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Connection	Line Voltage (V_L)	Line Current (I_L)	Typical Use
Delta (Δ)	V_ph	√3 × I_ph	Industrial power transmission, motor windings

Table 1.6: Star vs. Delta three-phase connections.

Quick-Solve Case	Shortcut Formula	Worked Example
Peak given RMS	E_m = E_rms / 0.707 = 1.414×E_rms	E_rms=230V → E_m≈325V
RMS given Peak	E_rms = 0.707 × E_m	E_m=311V → E_rms≈220V
Angular frequency	ω = 2πf	f=50Hz → ω≈314 rad/s
Star V_L from V_ph	V_L = √3×V_ph	V_ph=230V → V_L≈398V
Delta I_L from I_ph	I_L = √3×I_ph	I_ph=10A → I_L≈17.3A
3-phase power	P = √3 V_L I_L cosφ	V_L=400V, I_L=10A, pf=0.8 → P≈5.54kW

Table 1.7: Quick-solve shortcuts for Section 1.3 numerical MCQs.

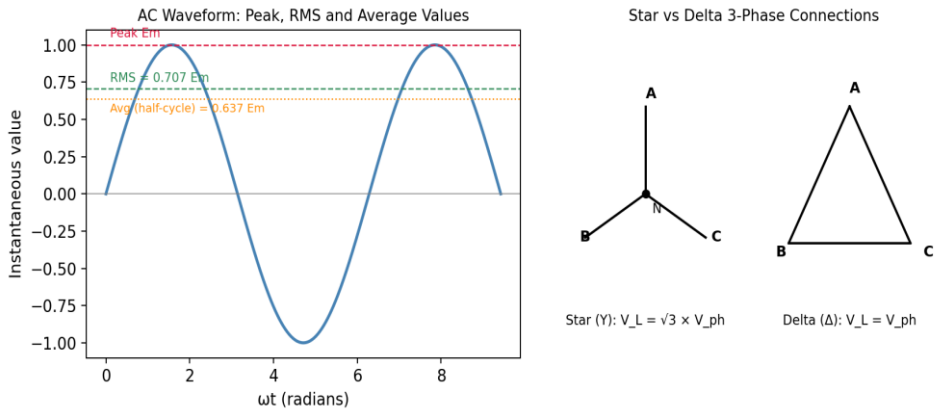


Fig. 1.3: (Left) A sinusoidal AC waveform showing peak, RMS and average values. (Right) Star and delta three-phase connections.

Solved MCQs

Q41. The RMS value of a pure sinusoidal AC waveform is related to its peak value E_m by:

(A) 0.5 E_m
(B) 0.637 E_m
(C) 0.707 E_m
(D) 1.414 E_m

Answer: (C) 0.707 E_m

Explanation: *For a pure sine wave, E_rms = 0.707 × E_m, which represents the effective (heating-equivalent) value of the alternating quantity.*

Q42. The form factor of a sinusoidal waveform is approximately:

(A) 1.0
(B) 1.11
(C) 1.414
(D) 0.637

Answer: (B) 1.11

Explanation: *Form factor = RMS/Average = 0.707E_m / 0.637E_m ≈ 1.11 for a pure sinusoid.*

Q43. In a star-connected, balanced 3-phase system, the line voltage is:

(A) Equal to the phase voltage
(B) √3 times the phase voltage
(C) 3 times the phase voltage
(D) Half the phase voltage

Answer: (B) √3 times the phase voltage

Explanation: *For a star connection, the line voltage is the phasor difference of two phase voltages 120° apart, which works out to √3 times the phase voltage magnitude.*

Q44. The phase difference between any two adjacent phases of a balanced 3-phase supply is:

(A) 60°
(B) 90°
(C) 120°
(D) 180°

Answer: (C) 120°

Explanation: *A standard three-phase supply consists of three voltages of equal magnitude and frequency, mutually displaced in phase by exactly 120° from each other.*

Q45. A sinusoidal voltage has a peak value of 325V. Its RMS value is approximately:

(A) 230V
(B) 325V
(C) 460V
(D) 207V

Answer: (A) 230V

Explanation: *$E_{rms} = 0.707 \times E_m = 0.707 \times 325 \approx 230V$ — the standard European/Nepali domestic mains RMS voltage.*

Q46. A sinusoidal supply has an RMS voltage of 220V. Its peak (maximum) value is approximately:

(A) 155V
(B) 220V
(C) 311V
(D) 381V

Answer: (C) 311V

Explanation: *$E_m = E_{rms} / 0.707 = 220/0.707 \approx 311V$.*

Q47. The angular frequency of a 50Hz AC supply is:

(A) 50 rad/s
(B) 100 rad/s
(C) 157 rad/s
(D) 314 rad/s

Answer: (D) 314 rad/s

Explanation: *$\omega = 2\pi f = 2\pi \times 50 \approx 314$ rad/s.*

Q48. A star-connected 3-phase source has a phase voltage of 230V. Its line voltage is approximately:

(A) 230V
(B) 398V
(C) 690V
(D) 133V

Answer: (B) 398V

Explanation: *$V_L = \sqrt{3} \times V_{ph} = 1.732 \times 230 \approx 398V$.*

Q49. A delta-connected load has a phase current of 10A. Its line current is approximately:

(A) 10A
(B) 17.3A

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(C) 30A
(D) 5.77A

Answer: (B) 17.3A

Explanation: *$I_L = \sqrt{3} \times I_{ph} = 1.732 \times 10 \approx 17.3A$.*

Q50. A balanced 3-phase load draws a line voltage of 400V and line current of 10A at a power factor of 0.8. The total active power is approximately:

(A) 3.2 kW
(B) 4 kW
(C) 5.54 kW
(D) 6.93 kW

Answer: (C) 5.54 kW

Explanation: *3-phase power $P = \sqrt{3} \times V_L \times I_L \times \cos\varphi = 1.732 \times 400 \times 10 \times 0.8 \approx 5.54$ kW.*

Q51. The neutral current in a perfectly balanced, star-connected 3-phase system is:

(A) Equal to the phase current
(B) Equal to the line current
(C) Zero
(D) Infinite

Answer: (C) Zero

Explanation: *In a perfectly balanced system, the three equal-magnitude phase currents, 120° apart, sum to exactly zero, so no current flows in the neutral wire.*

Q52. The peak (crest) factor of a pure sinusoidal waveform is approximately:

(A) 0.637
(B) 0.707
(C) 1.11
(D) 1.414

Answer: (D) 1.414

Explanation: *Crest factor = Peak/RMS = $E_m/(0.707E_m) = 1/0.707 \approx 1.414$ for a pure sine wave.*

Q53. An AC ammeter or voltmeter, unless otherwise stated, is calibrated to read:

(A) Peak value
(B) Average value
(C) RMS value
(D) Instantaneous value

Answer: (C) RMS value

Explanation: *Standard AC meters are calibrated to indicate the RMS value, since this is the value that corresponds to the equivalent steady (DC) heating/power effect.*

Q54. The average value of a pure sinusoid over one complete cycle is:

(A) 0.637 E_m
(B) 0.707 E_m
(C) Zero
(D) E_m

Answer: (C) Zero

Explanation: *Since a symmetric sine wave spends equal time above and below zero with mirror symmetry, its average over a full cycle is exactly zero; the 0.637E_m figure applies only to a half cycle.*

Q55. Compared to a single-phase system, a three-phase system for the same power delivery generally requires:

(A) More conductor material
(B) Less conductor material
(C) No conductors at all
(D) The same amount of conductor material

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Answer: (B) Less conductor material

Explanation: *For the same power delivered, a balanced 3-phase system requires less conductor material than an equivalent single-phase system, which is a key reason 3-phase is preferred for bulk power transmission.*

Q56. In a delta-connected 3-phase system, the relationship between line and phase voltage is:

(A) $V_L = \sqrt{3}\, V_{ph}$

(B) $V_L = V_{ph}$

(C) $V_L = 3V_{ph}$

(D) $V_L = V_{ph}/\sqrt{3}$

Answer: (B) $V_L = V_{ph}$

Explanation: *In a delta connection, each line terminal is directly connected across one phase winding, so the line voltage equals the phase voltage directly: $V_L = V_{ph}$.*

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1.4 Semiconductor Devices

1.4.1 PN Junction Diode

- A PN junction is formed by joining a p-type (majority carriers = holes) and n-type (majority carriers = free electrons) semiconductor; near the junction, a depletion region (free of mobile carriers) develops, with a built-in potential barrier.
- Forward bias: p-side connected to +ve, n-side to −ve terminal of the source; this narrows the depletion region and, once the applied voltage exceeds the cut-in (knee) voltage, the diode conducts with low resistance and rapidly rising current.
- Reverse bias: polarity reversed; the depletion region widens, and only a very small reverse saturation (leakage) current flows, until the reverse voltage becomes large enough to cause breakdown (avalanche or Zener breakdown).
- Typical cut-in (knee) voltage: ≈ 0.7 V for silicon diodes, ≈ 0.3 V for germanium diodes — silicon is far more common in modern devices due to better thermal stability and lower leakage current.

1.4.2 Bipolar Junction Transistor (BJT): Configurations and Biasing

- A BJT is a three-terminal current-controlled device (Emitter, Base, Collector) available in NPN and PNP forms; a small base current controls a much larger collector current, giving current gain.
- Current gain relations: $\alpha = I_C/I_E$ (common-base gain, always < 1), $\beta = I_C/I_B$ (common-emitter gain, typically 20–500); the two are related by $\beta = \alpha/(1-\alpha)$ and $\alpha = \beta/(\beta+1)$.
- Biasing sets the DC operating point (Q-point) in the desired region (usually the active region, for linear amplification) before any AC signal is applied; common biasing methods include fixed bias (simple but poor stability), collector-to-base bias, and voltage-divider bias (most widely used, since it gives the best Q-point stability against transistor parameter variation and temperature).
- Small-signal model: for small AC signals around the Q-point, the transistor is represented by a linear equivalent circuit (e.g., hybrid-π or h-parameter model) valid only for small excursions; the large-signal model instead uses the full non-linear exponential diode-like relations and is needed when signal swings are large (e.g., switching applications, power amplifiers).

1.4.3 MOSFET and CMOS

- A MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) is a voltage-controlled device: the gate voltage (isolated from the channel by a thin oxide layer) controls the channel's conductivity, drawing essentially zero DC gate current — giving MOSFETs very high input impedance, unlike the current-controlled BJT.
- MOSFET types: enhancement mode (channel must be induced by applying a sufficient gate voltage; normally OFF) and depletion mode (channel exists at zero gate bias and can be depleted/reduced by gate voltage; normally ON); each available in N-channel or P-channel versions.
- CMOS (Complementary MOS) technology pairs an NMOS and a PMOS transistor so that, in steady state, exactly one of the pair is OFF — giving extremely low static (standby) power dissipation, which is why CMOS is the dominant technology in virtually all modern digital ICs and microprocessors.

BJT Configuration	Current Gain	Voltage Gain	Typical Application
Common Emitter (CE)	High ($\beta = I_C/I_B$)	High	General-purpose amplifiers
Common Base (CB)	< 1 ($\alpha = I_C/I_E$)	High	High-frequency circuits

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BJT Configuration	Current Gain	Voltage Gain	Typical Application
Common Collector (CC)	High (emitter follower)	≈ 1	Impedance matching / buffer stage

Table 1.7: Comparison of the three BJT amplifier configurations.

Device	Control Mechanism	Input Impedance	Key Feature
BJT	Current-controlled (base current)	Moderate (low-to-medium)	Good current gain β; needs base drive current
MOSFET	Voltage-controlled (gate voltage)	Very high (gate insulated by oxide)	Near-zero gate current; ideal for low-power switching/digital logic

Table 1.8: BJT vs. MOSFET — key control-mechanism differences.

Quick-Solve Case	Shortcut Formula	Worked Example
β from α	$\beta = \alpha/(1-\alpha)$	$\alpha=0.98 \rightarrow \beta=49$
α from β	$\alpha = \beta/(\beta+1)$	$\beta=99 \rightarrow \alpha=0.99$
I_C from I_B (CE)	$I_C = \beta \times I_B$	$\beta=100$, $I_B=20\mu A \rightarrow I_C=2mA$
I_E from I_C, I_B	$I_E = I_C + I_B$	$I_C=2mA$, $I_B=20\mu A \rightarrow I_E=2.02mA$
Diode forward drop (Si)	$V_D \approx 0.7V$ (constant approx.)	Used to quickly estimate diode circuit voltages

Table 1.9: Quick-solve shortcuts for Section 1.4 numerical MCQs.

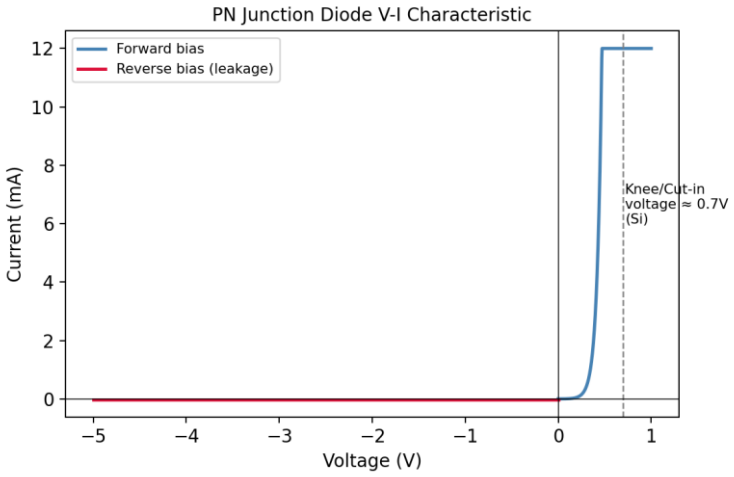


Fig. 1.4: PN junction diode V-I characteristic — negligible current until the forward cut-in voltage (≈0.7 V for silicon), then rapid conduction; only small leakage current flows in reverse bias.

Solved MCQs

Q57. The typical cut-in (knee) voltage of a silicon diode is about:

(A) 0.2 V
(B) 0.3 V
(C) 0.7 V
(D) 1.5 V

Answer: (C) 0.7 V

Explanation: *Silicon diodes have a cut-in (knee) voltage of approximately 0.7 V, above which forward current rises rapidly; germanium diodes have a lower cut-in voltage of about 0.3 V.*

Q58. In which BJT configuration is the current gain always less than unity?

(A) Common Emitter

(B) Common Base

(C) Common Collector

(D) None of the above

Answer: (B) Common Base

Explanation: *The Common Base configuration has current gain α = I_C/I_E, which is always slightly less than 1 since the collector current is always marginally smaller than the emitter current.*

Q59. A MOSFET is primarily a _____ controlled device.

(A) Current

(B) Voltage

(C) Power

(D) Frequency

Answer: (B) Voltage

Explanation: *MOSFET channel conductivity is controlled by the gate-source voltage across an insulating oxide layer, with negligible gate current flowing — making it a voltage-controlled device, unlike the current-controlled BJT.*

Q60. CMOS technology is preferred in digital ICs mainly because of its:

(A) High cost

(B) Low static power dissipation

(C) Large physical size

(D) Low switching speed

Answer: (B) Low static power dissipation

Explanation: *CMOS's complementary NMOS/PMOS structure ensures that, in steady state, one transistor of every pair is always OFF, giving very low static (standby) power consumption — essential for dense, battery-efficient digital ICs.*

Q61. A transistor has α = 0.98. Its β value is:

(A) 49

(B) 0.98

(C) 1.02

(D) 98

Answer: (A) 49

Explanation: *β = α/(1−α) = 0.98/0.02 = 49.*

Q62. A transistor has β = 99. Its α value is:

(A) 0.99

(B) 9.9

(C) 0.01

(D) 99

Answer: (A) 0.99

Explanation: *α = β/(β+1) = 99/100 = 0.99.*

Q63. A transistor with β=100 has a base current of 20μA. Its collector current is:

(A) 20μA

(B) 200μA

(C) 2mA

(D) 20mA

Answer: (C) 2mA

Explanation: *I_C = β × I_B = 100 × 20μA = 2000μA = 2mA.*

Q64. For a transistor with I_C=2mA and I_B=20μA, the emitter current I_E is approximately:

(A) 1.98mA

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(B) 2.00mA

(C) 2.02mA

(D) 2.20mA

Answer: (C) 2.02mA

Explanation: *$I_E = I_C + I_B = 2mA + 0.02mA = 2.02mA$.*

Q65. A silicon diode is forward biased with a 5V source in series with a 1kΩ resistor. Assuming a constant 0.7V diode drop, the current through the circuit is approximately:

(A) 5mA

(B) 4.3mA

(C) 0.7mA

(D) 50mA

Answer: (B) 4.3mA

Explanation: *The resistor drops $(5-0.7) = 4.3V$, so $I = 4.3V/1k\Omega = 4.3mA$.*

Q66. In reverse bias, a PN junction diode conducts:

(A) A large forward current

(B) Only a very small leakage current, until breakdown

(C) Zero current under all conditions

(D) Current equal to the forward current

Answer: (B) Only a very small leakage current, until breakdown

Explanation: *In reverse bias, the depletion region widens and only a small reverse saturation (leakage) current flows, until the reverse voltage is large enough to cause breakdown.*

Q67. Which BJT configuration is commonly used as a buffer/impedance-matching stage due to its near-unity voltage gain?

(A) Common Emitter

(B) Common Base

(C) Common Collector (emitter follower)

(D) None of the above

Answer: (C) Common Collector (emitter follower)

Explanation: *The Common Collector (emitter-follower) configuration has voltage gain ≈ 1 but high current gain and high input/low output impedance, making it ideal as a buffer stage.*

Q68. An enhancement-mode MOSFET is normally:

(A) ON at zero gate-source voltage

(B) OFF at zero gate-source voltage, requires sufficient V_GS to turn ON

(C) Always ON regardless of gate voltage

(D) Not a valid MOSFET type

Answer: (B) OFF at zero gate-source voltage, requires sufficient V_GS to turn ON

Explanation: *In an enhancement-mode MOSFET, no conducting channel exists at zero gate bias; a sufficient gate-source voltage must be applied to induce (enhance) the channel, so it is normally OFF.*

Q69. A depletion-mode MOSFET is normally:

(A) OFF at zero gate-source voltage

(B) ON at zero gate-source voltage; gate voltage can deplete the channel

(C) Unable to conduct at all

(D) Only available as a BJT variant

Answer: (B) ON at zero gate-source voltage; gate voltage can deplete the channel

Explanation: *A depletion-mode MOSFET has a pre-existing channel at zero gate bias (normally ON); applying a gate voltage of the appropriate polarity depletes (reduces) this channel, decreasing conduction.*

Q70. Compared to a BJT, a MOSFET's gate draws:

(A) A large, continuous DC current

(B) Essentially zero DC current (due to the insulating oxide layer)

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(C) Exactly the same current as a BJT's base

(D) Current only in reverse bias

Answer: (B) Essentially zero DC current (due to the insulating oxide layer)

Explanation: *The MOSFET gate is isolated from the channel by a thin oxide (insulating) layer, so essentially no DC current flows into the gate terminal, unlike the BJT base which requires continuous drive current.*

Q71. Voltage-divider bias is preferred over fixed bias in BJT circuits mainly because it provides:

(A) Lower cost only

(B) Better Q-point stability against β variation and temperature

(C) Higher voltage gain only

(D) No need for any resistors

Answer: (B) Better Q-point stability against β variation and temperature

Explanation: *Voltage-divider bias uses feedback (via the emitter resistor) to stabilise the operating point against variations in transistor β and temperature, making it the most stable and widely used biasing method.*

Q72. The small-signal model of a BJT is valid only for:

(A) Large signal swings covering the full load line

(B) Small AC signal excursions around a fixed DC operating (Q) point

(C) DC analysis only, never AC

(D) Reverse-biased operation only

Answer: (B) Small AC signal excursions around a fixed DC operating (Q) point

Explanation: *The small-signal (linear) model approximates the transistor's behaviour only for small AC variations around the Q-point; for large signal swings, the full non-linear large-signal model must be used instead.*

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1.5 Signal Generator (Oscillators)

1.5.1 Basic Principle of Oscillators

- An oscillator is a circuit that converts DC supply energy into a continuous, self-sustained AC (periodic) output waveform, without requiring any external AC input signal — achieved using positive feedback around an amplifier.
- Barkhausen Criterion (the condition for sustained oscillation): the loop gain magnitude must equal exactly 1 ($|A\beta| = 1$, where A is the amplifier gain and β is the feedback network's transfer ratio), and the total phase shift around the loop must be exactly 0° or 360° — if $|A\beta| < 1$ oscillations die out, and if $|A\beta| > 1$ momentarily, oscillations build up until non-linearity naturally limits the amplitude back to $|A\beta|=1$.

1.5.2 RC Oscillators (Audio-Frequency Range)

- RC Phase-Shift Oscillator: uses three (or more) cascaded RC sections in the feedback path, each contributing about 60° of phase shift, so that three sections together give the 180° shift needed to combine with the amplifier's own 180° inversion for a total 360° loop phase shift.
- Wien Bridge Oscillator: uses a lead-lag RC network in the feedback path; valued for its very stable, low-distortion sinusoidal output, making it the standard choice in most audio-frequency (AF) signal generators.

1.5.3 LC Oscillators (Radio-Frequency Range)

- Hartley Oscillator: uses a tapped inductor (two inductors in series, or a single inductor with a centre tap) as part of the resonant feedback network.
- Colpitts Oscillator: uses a tapped capacitor (two capacitors in series) instead of a tapped inductor for the feedback network — generally gives better frequency stability than Hartley since capacitors are easier to manufacture with tighter tolerance than inductors.

1.5.4 Crystal Oscillator

- A crystal oscillator exploits the piezoelectric effect of a quartz crystal, which mechanically vibrates at a highly precise, stable natural (resonant) frequency when an electric field is applied across it.
- Crystal oscillators offer by far the highest frequency stability of any oscillator type covered here (far exceeding RC or LC oscillators), which is why they are used almost universally as the timing reference in clocks, watches, and microprocessor/digital system clock generation.

1.5.5 Waveform Generators

- Beyond sinusoidal oscillators, dedicated waveform generator circuits (e.g., astable multivibrators, function generator ICs) produce square, triangular, or sawtooth waveforms, typically using comparators/switching elements combined with RC charging/discharging networks, rather than the resonant feedback loops used for sine-wave oscillators.

Oscillator Type	Frequency Range	Feedback Element	Key Feature
RC Phase-Shift	Audio frequency	Three RC sections (≈60° each)	Simple, moderate stability
Wien Bridge	Audio frequency	Lead-lag RC network	Very stable, low-distortion sine output
Hartley	Radio frequency	Tapped inductor	Simple LC tank; moderate stability

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Oscillator Type	Frequency Range	Feedback Element	Key Feature
Colpitts	Radio frequency	Tapped capacitor	Better frequency stability than Hartley
Crystal	Precision reference (wide range)	Piezoelectric quartz crystal	Highest frequency stability of all types

Table 1.9: Comparison of common oscillator types.

Oscillator	Frequency Formula	Worked Example
Wien Bridge (equal R,C legs)	$f = 1/(2\pi RC)$	R=10kΩ, C=10nF → f≈1.59kHz
Hartley (tank L_1+L_2, C)	$f = 1/(2\pi\sqrt{((L_1+L_2)C)})$	Same form as basic LC resonance
Colpitts (tank L, C_1C_2 series)	$f = 1/(2\pi\sqrt{(L\times C_eq)})$; $1/C_eq=1/C_1+1/C_2$	Uses equivalent series capacitance
RC Phase-Shift (3 identical sections)	$f = 1/(2\pi RC\sqrt{6})$	R=10kΩ, C=10nF → f≈650Hz

Table 1.10: Oscillator frequency formulas for quick numerical MCQs.

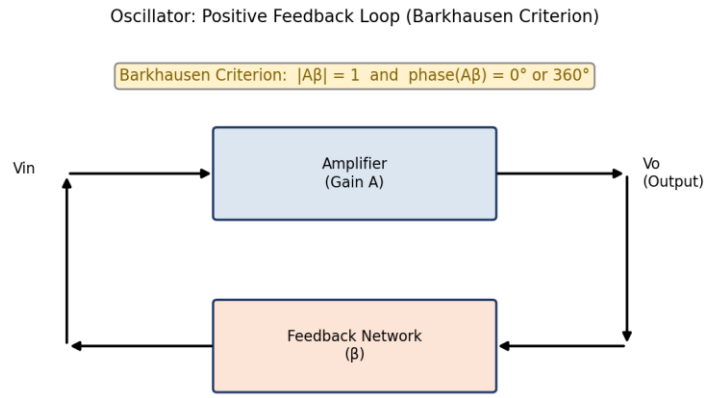


Fig. 1.5: General oscillator structure — an amplifier (gain A) and feedback network (β) form a positive-feedback loop satisfying the Barkhausen criterion.

Solved MCQs

Q73. The Barkhausen criterion for sustained oscillation requires the loop gain to be:

(A) Less than 1
(B) Exactly 1, with 0°/360° total phase shift
(C) Greater than 10
(D) Negative

Answer: (B) Exactly 1, with 0°/360° total phase shift

Explanation: *Sustained (constant-amplitude) oscillation requires $|A\beta| = 1$ exactly, together with a total loop phase shift of 0° or 360°, so the fed-back signal reinforces the original signal in both magnitude and phase.*

Q74. A Hartley oscillator uses which feedback element?

(A) Tapped capacitor
(B) Tapped inductor
(C) Resistor network
(D) Zener diode

Answer: (B) Tapped inductor

Explanation: *The Hartley oscillator's feedback network uses a tapped inductor (two inductors in series or a centre-tapped coil), while the Colpitts oscillator instead uses a tapped capacitor.*

Q75. Which type of oscillator offers the highest frequency stability?

(A) RC phase-shift oscillator

(B) Wien bridge oscillator

(C) Crystal oscillator

(D) Hartley oscillator

Answer: (C) Crystal oscillator

Explanation: *Crystal oscillators exploit the highly stable mechanical resonance of a piezoelectric quartz crystal, giving far greater frequency stability than RC or LC oscillator types.*

Q76. An RC phase-shift oscillator typically uses how many RC sections to obtain the required 180° phase shift?

(A) 1

(B) 2

(C) 3

(D) 5

Answer: (C) 3

Explanation: *Each RC stage contributes approximately 60° of phase shift; three cascaded stages together provide the 180° needed to combine with the amplifier's inherent 180° inversion for a full 360° loop.*

Q77. A Wien bridge oscillator has R=10kΩ and C=10nF in its equal-value RC legs. Its oscillation frequency is approximately:

(A) 159 Hz

(B) 1.59 kHz

(C) 15.9 kHz

(D) 159 kHz

Answer: (B) 1.59 kHz

Explanation: $f = 1/(2\pi RC) = 1/(2\pi \times 10000 \times 10 \times 10^{-9}) = 1/(2\pi \times 10^{-4}) \approx 1.59$ *kHz.*

Q78. Which oscillator uses a tapped capacitor in its feedback network?

(A) Hartley oscillator

(B) Colpitts oscillator

(C) RC phase-shift oscillator

(D) Crystal oscillator

Answer: (B) Colpitts oscillator

Explanation: *The Colpitts oscillator uses two series capacitors (a tapped capacitor arrangement) to form its resonant feedback network, in contrast to the Hartley oscillator's tapped inductor.*

Q79. The piezoelectric effect, exploited in crystal oscillators, refers to a material that:

(A) Generates light when a voltage is applied

(B) Mechanically vibrates at a precise frequency when an electric field is applied

(C) Changes colour with temperature

(D) Conducts only in one direction

Answer: (B) Mechanically vibrates at a precise frequency when an electric field is applied

Explanation: *The piezoelectric effect causes certain crystals (notably quartz) to mechanically deform/vibrate when an electric field is applied, and vice versa, at a very precise and stable natural frequency.*

Q80. Which of the following is NOT a sinusoidal oscillator?

(A) Wien bridge oscillator

(B) Colpitts oscillator

(C) Astable multivibrator

(D) Crystal oscillator

Answer: (C) Astable multivibrator

Explanation: *An astable multivibrator is a switching (relaxation) circuit that produces a square/rectangular waveform using RC charging/discharging, not a resonant feedback loop producing a sine wave.*

EASY EXPLANATION

Q81. In an oscillator, if the loop gain |Aβ| momentarily exceeds 1, the amplitude of oscillation:

(A) Immediately drops to zero

(B) Builds up until non-linearity limits it back to |Aβ|=1

(C) Stays exactly constant regardless

(D) Becomes negative

Answer: (B) Builds up until non-linearity limits it back to |Aβ|=1

Explanation: *When |Aβ|>1, the oscillation amplitude grows on each cycle until amplifier non-linearity (saturation) naturally reduces the effective gain back to the steady-state condition |Aβ|=1.*

Q82. The output waveform of a well-designed Wien bridge oscillator is characterised mainly by:

(A) High distortion and instability

(B) Very low distortion and good amplitude stability

(C) A square wave shape

(D) A sawtooth wave shape

Answer: (B) Very low distortion and good amplitude stability

Explanation: *The Wien bridge oscillator's lead-lag network and (typically) amplitude-stabilising feedback give it a very stable, low-distortion sinusoidal output, making it the standard for audio-frequency signal generators.*

Q83. If the loop gain of an oscillator is |Aβ| < 1, the oscillations will:

(A) Grow without bound

(B) Die out (decay to zero)

(C) Continue at constant amplitude

(D) Reverse phase every cycle

Answer: (B) Die out (decay to zero)

Explanation: *If the loop gain magnitude is less than 1, each successive cycle's signal is smaller than the last, so any oscillation naturally decays to zero rather than being sustained.*

Q84. Function generator ICs that produce square, triangular or sawtooth waveforms typically rely on:

(A) A quartz crystal resonator only

(B) Comparators/switching elements with RC charging and discharging

(C) A tapped inductor LC tank

(D) A tapped capacitor LC tank

Answer: (B) Comparators/switching elements with RC charging and discharging

Explanation: *Non-sinusoidal waveform generators use comparator/switching stages combined with RC charge/discharge timing, rather than the resonant LC or crystal feedback loops used for sine-wave oscillators.*

Q85. Compared to LC oscillators, crystal oscillators are generally used when the priority is:

(A) Very high frequency stability, even if tunability is limited

(B) Wide, continuously variable tuning range

(C) Lowest possible component count

(D) Producing a square waveform

Answer: (A) Very high frequency stability, even if tunability is limited

Explanation: *Crystal oscillators sacrifice easy tunability (a crystal resonates at close to one fixed frequency) in exchange for extremely high frequency stability, which is why they are used as fixed precision references (clocks, microprocessors).*

MCQ EXPLANATION

1.6 Amplifiers

1.6.1 Classification of Output Stages

- Class A: the transistor conducts for the entire 360° of the input cycle (biased in the middle of its active region) — gives the least distortion and most linear output, but at low efficiency (theoretical maximum ≈ 25–50%) since the device dissipates significant power even with no signal.
- Class B: each of a complementary pair of transistors conducts for only 180° (half cycle) each, working together in a push-pull arrangement to reconstruct the full waveform — much higher efficiency (theoretical maximum ≈ 78.5%), but suffers from crossover distortion near the zero-crossing point, where neither transistor is properly conducting.
- Class AB: a compromise where each transistor is biased to conduct slightly more than 180° (but less than 360°) — this small idle bias current removes the crossover distortion of Class B while keeping efficiency close to Class B's, making Class AB the standard choice for practical audio power amplifiers.

1.6.2 Power BJTs and Push-Pull Stages

- Power BJTs are specifically designed to handle high current, voltage and power dissipation; because significant heat is generated, they require heat sinks (and sometimes forced-air/liquid cooling) to keep junction temperature within safe limits.
- Transformer-coupled push-pull stage: uses an input and/or output transformer for coupling and impedance matching between driver and output transistors (or between the output stage and the load) — commonly operated in Class B for high efficiency, historically important in audio power amplifier design before direct-coupled complementary-symmetry designs became more common.

1.6.3 Tuned Amplifiers

- A tuned amplifier uses an LC tank circuit (parallel inductor-capacitor combination) as its load instead of a plain resistor — since the tank's impedance peaks sharply at its resonant frequency (Section 1.2), the amplifier selectively amplifies only a narrow band of frequencies around resonance, rejecting others.
- Tuned amplifiers are the standard building block of RF (Radio Frequency) and IF (Intermediate Frequency) amplifier stages in radio receivers and transmitters, where selecting one desired channel/frequency band while rejecting all others is essential.

1.6.4 Operational Amplifier (Op-Amp)

- An op-amp is a high-gain differential amplifier IC, forming the building block of countless analog signal-processing circuits (amplifiers, filters, oscillators, comparators, etc.).
- Ideal op-amp characteristics: infinite open-loop gain, infinite input impedance (zero input current at both terminals), zero output impedance, infinite bandwidth, and zero offset voltage — real op-amps only approximate these, but the ideal model is an excellent and widely used first-order approximation for circuit analysis.
- Virtual short concept: for an ideal op-amp operating with negative feedback, the two input terminals are forced to the same potential (V+ = V−) while drawing no input current into either terminal — this single principle is the key to solving the overwhelming majority of op-amp circuit analysis problems (inverting amplifier, non-inverting amplifier, summing amplifier, integrator, differentiator, etc.).

Class	Conduction Angle	Typical Efficiency	Distortion Characteristic
Class A	360° (full cycle)	Low (≈25–50%)	Least distortion, most linear

EASY EXPLANATION

Class	Conduction Angle	Typical Efficiency	Distortion Characteristic
Class B	180° (half cycle, push-pull)	High (≈78.5% max)	Crossover distortion near zero-crossing
Class AB	Between 180° and 360°	Between Class A and B	Reduced crossover distortion (practical compromise)

Table 1.10: Comparison of amplifier output-stage classes.

Op-Amp Ideal Characteristic	Value	Practical Consequence
Open-loop gain	Infinite	With feedback, closed-loop gain set purely by external components
Input impedance	Infinite	Zero current drawn into either input terminal
Output impedance	Zero	Output voltage unaffected by load current drawn
Bandwidth	Infinite	Gain assumed constant at all frequencies (ideal case)
Offset voltage	Zero	Output is exactly zero when both inputs are equal

Table 1.11: Ideal operational amplifier characteristics and their practical implications.

Op-Amp Circuit	Closed-Loop Gain Formula	Worked Example
Inverting amplifier	$A_v = -R_f/R_{in}$	$R_f=20k\Omega$, $R_{in}=2k\Omega \rightarrow A_v=-10$
Non-inverting amplifier	$A_v = 1 + R_f/R_{in}$	$R_f=9k\Omega$, $R_{in}=1k\Omega \rightarrow A_v=10$
Voltage follower (buffer)	$A_v = 1$	Output directly follows input
Summing amplifier (inverting)	$V_o = -R_f(V_1/R_1+V_2/R_2+...)$	Equal $R_1=R_2=R_f \rightarrow V_o=-(V_1+V_2)$

Table 1.12: Common op-amp configurations and their gain formulas for quick numerical solving.

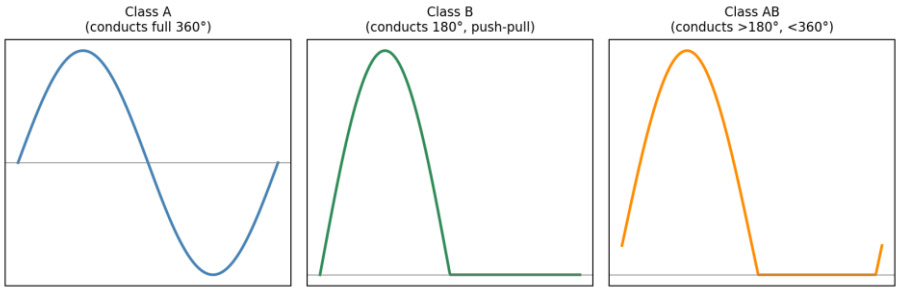


Fig. 1.6: Output conduction waveforms for Class A (full 360°), Class B (180°, push-pull) and Class AB (between 180° and 360°) amplifier stages.

Solved MCQs

Q86. A Class A amplifier conducts for:

(A) 180° of the input cycle
(B) 90° of the input cycle
(C) 360° (the full cycle)

(D) Less than 90°

Answer: (C) 360° (the full cycle)

Explanation: *Class A amplifiers are biased so the transistor conducts through the entire 360° input cycle, giving the least distortion of any class but at the cost of relatively low efficiency.*

Q87. Crossover distortion is a characteristic problem of:

(A) Class A amplifiers

(B) Class B push-pull amplifiers

(C) Ideal op-amps

(D) Zener voltage regulators

Answer: (B) Class B push-pull amplifiers

Explanation: *In Class B, each transistor of the complementary pair conducts only half the cycle; near the zero-crossing point neither transistor is properly conducting, creating a small 'dead zone' known as crossover distortion.*

Q88. A tuned amplifier uses which circuit as its load to selectively amplify a narrow band of frequencies?

(A) A simple resistor

(B) An LC tank circuit

(C) An RC network only

(D) A Zener diode

Answer: (B) An LC tank circuit

Explanation: *The LC tank circuit's impedance peaks sharply at its resonant frequency, so using it as the amplifier's load provides high gain only for frequencies near resonance and much lower gain elsewhere.*

Q89. For an ideal operational amplifier, the input impedance is:

(A) Zero

(B) Very low but non-zero

(C) Infinite

(D) Equal to the output impedance

Answer: (C) Infinite

Explanation: *An ideal op-amp is assumed to draw no current into either input terminal, which corresponds to infinite input impedance — the basis of the widely used 'virtual short' analysis technique.*

Q90. An inverting amplifier has R_f=20kΩ and R_in=2kΩ. Its closed-loop voltage gain is:

(A) +10

(B) −10

(C) +0.1

(D) −0.1

Answer: (B) −10

Explanation: *A_v = −R_f/R_in = −20k/2k = −10 (inverted, gain magnitude 10).*

Q91. A non-inverting amplifier has R_f=9kΩ and R_in=1kΩ. Its closed-loop voltage gain is:

(A) 9

(B) 10

(C) 0.9

(D) 1

Answer: (B) 10

Explanation: *A_v = 1 + R_f/R_in = 1 + 9k/1k = 1+9 = 10.*

Q92. The theoretical maximum efficiency of a Class B push-pull amplifier is approximately:

(A) 25%

(B) 50%

(C) 78.5%

(D) 100%

Answer: (C) 78.5%

EASY EXPLANATION

Explanation: *Class B amplifiers have a theoretical maximum efficiency of about 78.5% (π/4), significantly higher than Class A's 25–50%, because each transistor only dissipates power during its own half-cycle of conduction.*

Q93. A voltage follower (unity-gain buffer) built from an op-amp has a closed-loop gain of:

(A) 0

(B) 1

(C) Infinite

(D) −1

Answer: (B) 1

Explanation: *A voltage follower directly connects the output to the inverting input (100% feedback), giving a closed-loop gain of exactly 1 — used purely for its high input/low output impedance buffering property.*

Q94. Class AB amplifiers are used mainly to:

(A) Increase distortion compared to Class B

(B) Reduce Class B's crossover distortion while keeping good efficiency

(C) Reduce amplifier bandwidth

(D) Eliminate the need for any biasing

Answer: (B) Reduce Class B's crossover distortion while keeping good efficiency

Explanation: *Class AB slightly forward-biases both output transistors so a small current always flows, removing the crossover 'dead zone' of Class B while sacrificing only a little efficiency.*

Q95. Power BJTs used in amplifier output stages require heat sinks primarily because:

(A) They operate at very low current

(B) They dissipate significant heat due to high current/voltage/power handling

(C) They are voltage-controlled devices

(D) They have infinite input impedance

Answer: (B) They dissipate significant heat due to high current/voltage/power handling

Explanation: *Power transistors handle large currents and voltages, dissipating substantial heat as power loss; heat sinks (and sometimes forced cooling) are needed to keep the junction temperature within safe operating limits.*

Q96. A summing inverting amplifier has two equal input resistors $R_1=R_2=R_f$, with inputs $V_1=2V$ and $V_2=3V$. The output voltage is:

(A) +5V

(B) −5V

(C) +1V

(D) −1V

Answer: (B) −5V

Explanation: *For equal resistors, $V_o = -(V_1+V_2) = -(2+3) = -5V$.*

Q97. The 'virtual short' concept for an ideal op-amp with negative feedback states that:

(A) The two inputs draw large equal currents

(B) The two input terminals are at the same potential and draw no current

(C) Output impedance is infinite

(D) Open-loop gain is zero

Answer: (B) The two input terminals are at the same potential and draw no current

Explanation: *Under negative feedback, an ideal op-amp forces $V+ = V-$ (virtual short) while drawing no current into either input terminal — the single most useful principle for solving op-amp circuits.*

Q98. A transformer-coupled push-pull output stage is commonly operated in which class for high efficiency?

(A) Class A

(B) Class B

(C) Class C only

(D) None of the above

Answer: (B) Class B

EASY EXPLANATION

Explanation: *Transformer-coupled push-pull stages are commonly operated in Class B, where each transistor handles one half-cycle, giving much higher efficiency than a single Class A stage.*

Q99. Tuned amplifiers are most commonly used in which part of a communication system?

(A) Baseband audio power amplification

(B) RF/IF amplifier stages in radio receivers/transmitters

(C) DC power supply regulation

(D) Digital logic gates

Answer: (B) RF/IF amplifier stages in radio receivers/transmitters

Explanation: *Because tuned amplifiers selectively amplify only a narrow band of frequencies around resonance, they are the standard building block for RF and IF stages, where channel/frequency selection is essential.*

Q100. An ideal op-amp has zero offset voltage, meaning:

(A) The output is always non-zero

(B) The output is exactly zero when both input terminals are at equal potential

(C) The gain is always zero

(D) It cannot amplify DC signals

Answer: (B) The output is exactly zero when both input terminals are at equal potential

Explanation: *Zero offset voltage means that when V+ = V− exactly, the ideal op-amp's output is precisely zero — real op-amps have a small non-zero offset that this ideal model ignores.*

EASY EXPLANATION