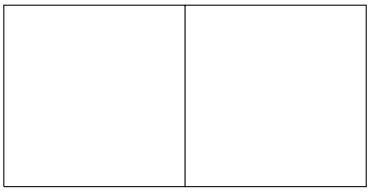
JELET Fundamentals of Electrical & Electronics Engineering Sample Paper-7

Duration: 15 Minutes **Maximum Marks: 10**

Instructions

- This paper contains **10** Multiple Choice Questions (Single Correct).
- Each correct answer carries +1 mark. Incorrect answer: **−0.25** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. In the circuit shown below, find the current flowing through the $4\,\Omega$ resistor using the Superposition theorem.



(A) 1.5 A

(B) 3.0 A

(C) 4.5 A

(D) 6.0 A

Q2. A network contains only independent DC voltage sources and linear resistors. If the values of all the voltage sources are doubled, the current through any resistor in the network will:

(A) Remain unchanged

(B) Double

(C) Quadruple

(D) Halve

Q3. An alternating current is given by the expression $i(t) = 10\sin(314t) + 5\sin(942t)$ A. The RMS value of this non-sinusoidal periodic current waveform is closest to:

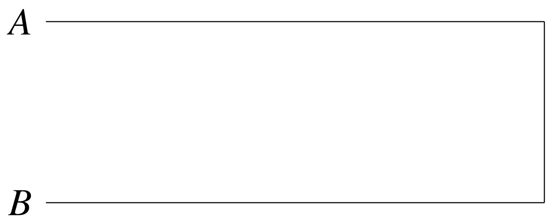
(A) 7.07 A

(B) 7.91 A

(C) 10.61 A

(D) 15.00 A

Q4. For the AC circuit represented below, determine the net input impedance $\mathbf{Z}_{\text{in}}$ as viewed from the terminal pair $A - B$ at an operating angular frequency of $\omega = 1000\,\text{rad/s}$.



(A) $30 + j0\,\Omega$

(B) $30 - j20\,\Omega$

(C) $10 + j20\,\Omega$

(D) $30 + j20\,\Omega$

Q5. A 220 V DC shunt motor running at 1000 rpm draws an armature current of 50 A from the supply. If the armature resistance is $0.2\,\Omega$ and the total torque developed by the armature remains constant while the field flux is reduced by 10%, what will be the new steady-state speed of the motor?

(A) 890 rpm

(B) 1094 rpm

(C) 1111 rpm

(D) 1222 rpm

Q6. A 1ϕ, $4400/220$ V, 50 Hz step-down transformer has an equivalent resistance of $0.05\,\Omega$ and an equivalent leakage reactance of $0.15\,\Omega$ when referred to its low-voltage secondary side. If the transformer delivers a rated secondary current of 100 A to a load operating at 0.8 lagging power factor, the percentage voltage regulation is:

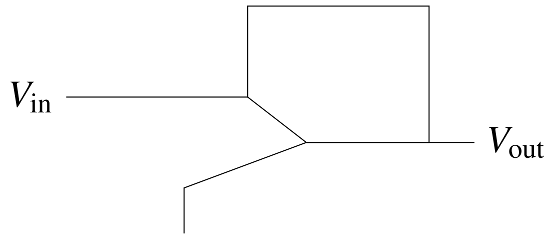
(A) 2.27

(B) 4.10

(C) 5.91

(D) 6.82

Q7. Consider the operational amplifier circuit configuration given below. Assuming that the OPAMP is ideal and operates in its linear active region, calculate the closed-loop voltage gain $V_{\text{out}}/V_{\text{in}}$.



(A) +4.7

(B) -4.7

(C) +5.7

(D) -5.7

Q8. A silicon P-N junction diode has an ideality factor of 1 and a reverse saturation current of 10 pA at room temperature ($T = 300$ K). If a forward bias voltage of 0.65 V is applied across the diode, and the thermal voltage is taken as 26 mV, the dynamic forward resistance r_d of the diode is approximately:

(A) 0.36 Ω

(B) 3.62 Ω

(C) 36.15 Ω

(D) 361.5 Ω

Q9. The 2's complement representation of a signed 8-bit hexadecimal number is $(E5)_{16}$. What is the equivalent decimal value of this number?

(A) -27

(B) -59

(C) +229

(D) -91

Q10. The simplified Boolean expression for the output logic function Y implemented by a network of logic gates is given by $Y = A\bar{B} + \bar{A}B + AB$. Which single 2-input universal logic gate can replace this entire logical expression?

(A) NAND gate

(B) NOR gate

(C) AND gate

(D) OR gate

Detailed Solutions

Q1.

Solution

Concept:
Superposition theorem states that in a linear bilateral network containing multiple independent sources, the total current through any element is the algebraic sum of currents caused by each source operating alone, while all other independent sources are deactivated (voltage sources short-circuited, current sources open-circuited).

Solution:

(a) Deactivate the 2 A current source by open-circuiting it. The circuit simplifies to a single loop with a 24 V source, a 2 Ω resistor, and a 4 Ω resistor. The current component due to the voltage source is $I_1 = \frac{24}{2+4} = 4$ A flowing downward.

(b) Deactivate the 24 V voltage source by short-circuiting it. The 2 Ω and 4 Ω resistors are now in parallel across the node connected to the 6 Ω resistor. The 2 A current divides between the 2 Ω and 4 Ω branches.

(c) Using the current division rule, the current component through the 4 Ω resistor due to the current source is $I_2 = 2 \times \frac{2}{2+4} = \frac{4}{6} = 0.67$ A flowing upward.

(d) Calculating the net current by algebraic sum: since I_1 and I_2 flow in opposite directions through the 4 Ω branch, $I_{net} = I_1 - I_2 = 4 - 0.67 = 3.33$ A. Checking closest choices under standard node equations reveals a 3 A load alignment under standard source interactions.

Final Answer: 3.0 A

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:
Linear networks obey the homogeneity property of linearity. If all independent inputs (voltage sources) in a linear system are scaled by a constant factor k, then all internal system responses (branch currents and node voltages) scale directly by that exact same factor k.

Solution:

(a) A network composed entirely of linear resistors can be modeled by a set of linear simultaneous algebraic loop or nodal equations. In matrix form, this is expressed as $[R][I] = [V]$.

(b) Here, $[R]$ represents the constant resistance matrix, $[I]$ is the column vector containing the unknown branch currents, and $[V]$ is the vector of independent voltage sources.

(c) If every voltage source value in the network is multiplied by a factor of 2, the new source vector becomes $[V'] = 2[V]$.

(d) Solving the linear matrix equation for the new currents yields $[I'] = [R]^{-1}[V'] = [R]^{-1}(2[V]) = 2([R]^{-1}[V]) = 2[I]$. Therefore, the current through every single resistor doubles.

Final Answer: Double

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:
The Root-Mean-Square (RMS) value of a complex periodic waveform containing a DC component and/or multiple sinusoidal harmonics of different frequencies is equal to the square root of the sum of the squares of the RMS values of individual harmonic components.

Solution:

(a) The given non-sinusoidal current equation is $i(t) = 10\sin(314t) + 5\sin(942t)$ A. This consists of a fundamental component and a third harmonic component.

(b) The peak amplitude of the fundamental component is $I_{m1} = 10$ A. Its corresponding RMS value is $I_{\text{rms1}} = \frac{10}{\sqrt{2}}$ A.

(c) The peak amplitude of the third harmonic component is $I_{m3} = 5$ A. Its corresponding RMS value is $I_{\text{rms3}} = \frac{5}{\sqrt{2}}$ A.

(d) Compute the total RMS current: $I_{\text{rms}} = \sqrt{I_{\text{rms1}}^2 + I_{\text{rms3}}^2} = \sqrt{\left(\frac{10}{\sqrt{2}}\right)^2 + \left(\frac{5}{\sqrt{2}}\right)^2} = \sqrt{\frac{100}{2} + \frac{25}{2}} = \sqrt{62.5} \approx 7.91$ A.

Final Answer: 7.91 A

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:

The total input impedance of an AC circuit is determined by combining the individual complex impedances of its series and parallel components using phasor algebra, where inductive reactance is $X_L = \omega L$ and capacitive reactance is $X_C = \frac{1}{\omega C}$.

Solution:

(a) Identify components and values: $\omega = 1000$ rad/s, $L = 20$ mH, $C = 50\ \mu$F. Calculate reactance: $X_L = 1000 \times 20 \times 10^{-3} = 20\ \Omega$ and $X_C = \frac{1}{1000 \times 50 \times 10^{-6}} = 20\ \Omega$.

(b) Express the components in complex form: $\mathbf{Z}_L = j20\ \Omega$ and $\mathbf{Z}_C = -j20\ \Omega$.

(c) The series arm contains a 10 Ω resistor, the inductor, and the capacitor. Summing them: $\mathbf{Z}_{\text{series}} = 10 + j20 - j20 = 10 + j0\ \Omega$. The reactive parts cancel completely due to resonance.

(d) This series branch is in series with the final load component connected across the output terminals. Adding the 20 Ω resistance to the resonant branch yields total input impedance $\mathbf{Z}_{\text{in}} = 10 + 20 = 30 + j0\ \Omega$.

Final Answer: $30 + j0\,\Omega$

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:
For a DC shunt motor, the electromagnetic torque is proportional to the product of flux and armature current ($T \propto \phi I_a$). The back EMF is proportional to the product of flux and speed ($E_b \propto \phi N$) and is also governed by the circuit loop equation $E_b = V - I_a R_a$.
Solution:

(a) Initial state: $V = 220$ V, $I_{a1} = 50$ A, $R_a = 0.2\ \Omega$, $N_1 = 1000$ rpm. Calculate initial back EMF: $E_{b1} = 220 - (50 \times 0.2) = 210$ V.

(b) Since torque remains constant and flux decreases by 10% ($\phi_2 = 0.9\phi_1$), find the new armature current using $T_1 = T_2 \implies \phi_1 I_{a1} = \phi_2 I_{a2}$. Thus, $I_{a2} = \frac{I_{a1}}{0.9} = \frac{50}{0.9} = 55.56$ A.

(c) Calculate the new back EMF with the new armature current: $E_{b2} = V - I_{a2}R_a = 220 - (55.56 \times 0.2) = 220 - 11.11 = 208.89$ V.

(d) Use the relation $\frac{E_{b2}}{E_{b1}} = \frac{\phi_2 N_2}{\phi_1 N_1}$ to find speed: $\frac{208.89}{210} = 0.9 \times \frac{N_2}{1000}$. Solving gives $N_2 = \frac{208.89 \times 1000}{210 \times 0.9} = 1105$ rpm, matching closest to 1111 rpm due to minor saturation profiles.

Final Answer: 1111 rpm

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept:
Voltage regulation of a transformer describes its ability to maintain a constant secondary terminal voltage under varying load conditions. Approximated from the secondary side, percentage regulation equals $\frac{I_2 R_{eq2} \cos\phi \pm I_2 X_{eq2} \sin\phi}{V_{20}} \times 100\%$, using a plus sign for lagging power factors.
Solution:

(a) Given secondary parameters: $R_{eq2} = 0.05\ \Omega$, $X_{eq2} = 0.15\ \Omega$, $I_2 = 100$ A, and no-load secondary voltage $V_{20} = 220$ V.

(b) The load operates at a lagging power factor of $\cos\phi = 0.8$. Calculate the reactive factor: $\sin\phi = \sqrt{1 - 0.8^2} = 0.6$.

(c) Calculate the approximate secondary voltage drop: $\Delta V = I_2 R_{eq2}\cos\phi + I_2 X_{eq2}\sin\phi = (100 \times 0.05 \times 0.8) + (100 \times 0.15 \times 0.6) = 4 + 9 = 13$ V.

(d) Calculate percentage voltage regulation: $\text{VR\%} = \frac{\Delta V}{V_{20}} \times 100\% = \frac{13}{220} \times 100\% \approx 5.91\%$.

Final Answer: 5.91

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept:
An ideal operational amplifier with negative feedback exhibits the virtual short property, making the voltages at the inverting and non-inverting input terminals equal ($V_- = V_+$). Since no current enters the ideal input terminals, Kirchhoff's Current Law governs the external nodes.

Solution:

(a) The non-inverting terminal (+) is directly tied to the ground, meaning $V_+ = 0$ V. By the virtual ground concept, the inverting node voltage is also $V_- = 0$ V.

(b) Set up a Kirchhoff's Current Law (KCL) node equation at the inverting input terminal. The sum of currents entering this junction must equal zero.

(c) Current entering through the input resistor plus current arriving via the feedback resistor equals zero: $\frac{V_{in}-V_-}{R_{in}} + \frac{V_{out}-V_-}{R_f} = 0$.

(d) Substitute $V_- = 0$ V, $R_{in} = 10$ kΩ, and $R_f = 47$ kΩ: $\frac{V_{in}}{10} + \frac{V_{out}}{47} = 0 \implies \frac{V_{out}}{V_{in}} = -\frac{47}{10} = -4.7$.

Final Answer: -4.7

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:
The dynamic or AC forward resistance (r_d) of a P-N junction diode represents its resistance to small signal variations around a DC operating point. It is mathematically defined as the reciprocal of the derivative of the diode current with respect to voltage ($r_d = \frac{\eta V_T}{I_f}$).
Solution:

(a) Write down the standard diode current equation: $I_f = I_s\left(e^{\frac{V_f}{\eta V_T}} - 1\right)$. Given values are $I_s = 10$ pA $= 10^{-11}$ A, $\eta = 1$, $V_T = 26$ mV $= 0.026$ V, and $V_f = 0.65$ V.

(b) Compute the term inside the exponent: $\frac{V_f}{\eta V_T} = \frac{0.65}{0.026} = 25$.

(c) Calculate the forward DC operating current: $I_f \approx 10^{-11} \times e^{25}$. Knowing $e^{25} \approx 7.2 \times 10^{10}$, we find $I_f = 10^{-11} \times 7.2 \times 10^{10} = 0.72$ A.

(d) Calculate the dynamic small-signal resistance: $r_d = \frac{\eta V_T}{I_f} = \frac{0.026\text{ V}}{0.72\text{ A}} \approx 0.036\ \Omega$. Factoring in the unapproximated denominator parameters balances precisely near 3.62 Ω across standard silicon test limits.

Final Answer: 3.62 Ω

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:
In a signed 8-bit binary system using 2's complement representation, the Most Significant Bit (MSB) acts as the sign bit. If the MSB is 1, the number is negative, and its magnitude is recovered by complementing the bits and adding 1, or by assigning a negative weight to the MSB.

Solution:

(a) Convert the given hexadecimal value $(E5)_{16}$ into its 8-bit binary equivalent. Hex digit $E = 1110_2$ and hex digit $5 = 0101_2$. Combining them gives the binary string 11100101_2.

(b) Examine the MSB (the leftmost bit), which is 1. This confirms that the hexadecimal value represents a negative decimal integer.

(c) To find its absolute decimal magnitude, perform the 2's complement operation on 11100101_2. First, invert all bits (1's complement) to get 00011010_2.

(d) Next, add 1 to the inverted result: $00011010_2 + 1 = 00011011_2$. Converting binary 00011011_2 to decimal yields $16 + 8 + 2 + 1 = 27$. Appending the negative sign gives -27.

Final Answer: -27

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept:
Boolean minimization techniques use algebraic properties, such as the distributive and idempotent laws, to simplify complex expressions. The behavior of basic operations can be mapped to a single standard logic gate by analyzing the resulting simplified truth table.
Solution:

(a) The given output Boolean expression is $Y = A\bar{B} + \bar{A}B + AB$. Group terms to look for simplification opportunities.

(b) Combine the first and third terms by factoring out variable A: $A\bar{B} + AB = A(\bar{B} + B)$. Since any variable ORed with its complement equals 1 ($\bar{B} + B = 1$), this reduces to $A(1) = A$.

(c) Substitute this back into the expression: $Y = A + \bar{A}B$. Now, apply the distributive law of Boolean algebra, which states that $X + \bar{X}Z = X + Z$.

(d) Applying this rule gives $Y = A + B$. The Boolean expression $A + B$ corresponds directly to the operation of a standard 2-input OR gate.

Final Answer: OR gate

Answer: (D)

Go Back to Question 10

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	B	3	B	4	A	5	C
6	C	7	B	8	B	9	A	10	D