Civil Services (Main) Examination, 2007

ELECTRICAL ENGINEERING

(Paper I)

Time Allowed : Three Hours **Maximum Marks : 300**

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.
Candidate has to attempt FIVE questions in all.
Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.
The number of marks carried by a question/part is indicated against it.
Wherever any assumptions are made for answering a question, they must be clearly indicated.
Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Answer any three of the following:

(a)(i) Determine the power delivered by 6 A source.

[Figure: Bridge network between a left node and a right node: upper branch 1 Ω (left) and 2 Ω (right) in series, meeting at an upper middle node; lower branch 4 Ω (left) and 3 Ω (right) in series, meeting at a lower middle node; a 5 V source connected between the upper middle node (+) and the lower middle node (−); an outer loop connects the left node and the right node through a current source marked 6 A (drawn in the bottom wire, arrow pointing right, i.e. towards the right node)] **10**

(a)(ii) For the circuit shown in the figure determine V_0/I_s using nodal analysis.

[Figure: All elements between a top wire and a common bottom wire: (from left) independent current source I_s (arrow up), resistor R_s, resistor R_1 connected at node V (current I_b flowing down through R_1); resistor R_2 in the top wire from node V to the output node V_0; at the output node a dependent current source μI_b (arrow down) and resistor R_3 to the bottom wire; output terminal V_0. $R_1=R_2=R_3=R_s=1$, $\mu=3$] **10**

(b)(i) A partially filled truth table of a sequence generator (3-D flip-flops in cascade) is given below. Find the sequence generated. Q_0 is LSB and Q_2 is MSB.

State	Q_2	Q_1	Q_0
1	1		0
2	0		
3			
4	1		
5	0	1	
6			
7	1	1	
1		0	0

10

(b)(ii) A D/A converter has the lowest and the highest values of resistances 1 kΩ and 4 kΩ, respectively. If the bit-length of the converter is to be increased by 2, what would be the number of resistors required and their values? Draw the complete circuit of the new converter. **10**

(c) A 250 V, 50 hp, 1000-rpm d.c. shunt motor drives a load that requires a constant torque regardless of the speed of operation. The armature circuit resistance is 0.04 Ω. When this motor delivers rated power, the armature current is 160 A.

(c)(i) If the flux is reduced to 70% of its original value, find the new value of the armature current. **10**

(c)(ii) What is the new speed? **10**

(d)(i) List the sources of noise in bipolar transistor **10**

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(d)(ii) A 100 kΩ resistor is connected in parallel with a 100 pF capacitor Determine the effective noise bandwidth and the noise voltage appearing at the terminals of the combination at 27° C. **10**

2. (a)(i) Solve the following difference equation by use of the z transform method: $x(k+2)+3x(k+1)+2x(k)=0$, $x(0)=0$, $x(1)=1$ **10**

(a)(ii) Obtain the inverse z transform of:

$$X(z)=(2z^3+z)/((z-2)^2(z-1))$$ **10**

(b)(i) For a three-phase induction motor, establish the ratio of maximum torque to full-load torque in the form: $T_m/T_{FL}=1/2(\beta^2+S_{FL}^2)/\beta S_{FL}$ [?], where $\beta=r_2'/x_2'$ **10**

(b)(ii) An induction motor of squirrel cage type has starting current 5 times of full-load current and full-load slip, of 4%. Evaluate maximum torque and corresponding slip and relation of starting torque to full-load torque. Assume the stator impedance and magnetising current negligible. **10**

(c)(i) What is the essential difference in commutation performance of triac and two thyristors connected in antiparallel? **8**

(c)(ii) A battery is charged through a resistor R as shown: If E is 220 V (rms), E_b=100 V (dc) and R = 20 Ω, calculate the battery charging current and power supplied to the battery.

[Figure: Single loop: a.c. source $\sqrt{2}\,E\sin\omega t$; from its upper terminal a thyristor (anode towards the source, cathode towards R, gate lead at the cathode end) in series with resistor R to the + terminal (longer plate, upper) of battery E_b; the − terminal of the battery returns along the bottom wire to the lower terminal of the source] **12**

3. (a)(i) Write the Maxwell's equation in a lossy dielectric and explain that the electric field leads the magnetic field in time phase. **10**

(a)(ii) Explain the term intrinsic impedance and its value in free space. **5**

(a)(iii) From Maxwell's equation state the significance of the term $\varepsilon/\omega\sigma$. What will be its value for a good conductor and a good dielectric? **5**

(b) A three-phase 440 V, 60 Hz, star-connected eight-pole, 100-hp induction motor has the following parameters expressed per phase: r_1=0.06 Ω, $x_1=x_2'$=0.26 Ω, r_2'=0.048 Ω, r_c=107.5 Ω, x_ϕ=8.47 Ω, s=0.03. The rotational losses are 1600 W. Using the approximate equivalent circuit, determine (i) the input line current and power factor, (ii) the efficiency. **20**

(c)(i) What are the advantages of half-controlled converters over fully-controlled converters? Show the output voltage waveforms for controlled and uncontrolled halves of the converter and the resultant voltage. **10**

(c)(ii) The speed of a 20-hp, 220 V, 1000 rpm dc series motor is controlled by a single phase half-controlled full wave ideal converter Series field winding and armature winding have resistances 0.05 Ω and 0.12 Ω respectively. Input to converter is 230 V, 50 Hz supply. Calculate the motor torque, current and supply power factor at rated load and speed for firing delay angle α=30°. Assume motor current to be continuous and ripple free. Residual back emf constant is 0.08 V/ rad/sec and armature current, dependent back emf (or torque) constant is 0.04 Nm/A^2. **10**

4. (a)(i) Derive the condition of oscillation and the expression for the frequency of oscillations for the circuit shown. (Use mesh analysis and Barkhausen's criteria). Draw actual oscillator circuit with one operational amplifier and minimum number of RC elements.

[Figure: RC phase-shift network: three equal capacitors C in series along a horizontal line from the left node V_0 to the right terminal V; resistor R from the left node V_0, from the junction of the first and second capacitors and from the junction of the second and third capacitors to a common bottom line, which is grounded; an amplifier block A drawn above the network, with a wire rising from the left node V_0 and a wire rising from the right terminal V towards it (connections to the amplifier not completely drawn)] **15**

(a)(ii) The ac equivalent circuit of an N-P-N transistor circuit is shown below. Draw the actual circuit with biasing and coupling capacitors. **5**

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[Figure: Input V_i with input current I_b through resistor h_{ie} in the top wire to the output node V_o; from the output node to the common bottom wire a current source $h_{fe}I_b$ (arrow pointing up, towards the output node) and load resistor R_L in parallel; output V_o taken at the right end of the top wire]

(b)(i) Show that at 100% modulation index, power contained in one side band of AM system is $1/6^{th}$ of total power transmitted. **10**

(b)(ii) A standard AM transmission, sinusoidally modulated to a depth of 30%, produces side frequencies of 4.928 and 4.914 MHz. The amplitude of each side frequency is 75 V. Determine the amplitude and frequency of the carrier **5**

(b)(iii) Define conditional probability and random variable. **5**

(c)(i) Explain tropospheric scatter propagation. **10**

(c)(ii) A reflex klystron operates at the peak of the n = 2 mode. The dc power input is 40 mW and V_1/V_0=0.278. If 20% of the power delivered by the beam is dissipated in the cavity walls, find the power delivered to the load. Assume β_1=1 and $J_1(1.53)$=0.562. **10**

SECTION 'B'

5. Answer any Three of the following:

(a)(i) State and prove the frequency-shift theorem. Determine the Laplace transform of f(t) shown in the figure, using the frequency-shift theorem.

[Figure: Graph of f(t) against t: f(t) follows the decaying exponential envelope $e^{-1/2t}$ (arrow label) during the intervals 0 to 1, 2 to 3, 4 to 5, 6 to 7 and 8 to 9, and is zero in between (rectangular-topped pulses of unit width with exponentially decaying tops, starting from a peak at t = 0); t-axis marked 0, 1, 2, 3, 4, 5, 6, 7, 8] **10**

(a)(ii) A system has impulse response e^{-at}. What would be the response of the system, if it is excited by a delayed unit step function (delay = T)? **10**

(b)(i) The above circuit is intended for NOT operation for input levels 0 and 10 V. Calculate the minimum value of R for which this operation is possible. Assume h_{FE}=30, $V_{BE(sat)}$=0.8, $V_{CE(sat)}$=0.2 in respect of above silicon transistor.

[Figure (printed before the text): NPN transistor inverter: input V_i through a 10 kΩ resistor (current i_1) to the base node; from the base node a resistor R (current i_2 flowing down) to a −10 V supply; base current I_B into the base; collector connected through a 2 kΩ resistor (current I_C flowing down) to V_{CC}=10 V; output V_o taken at the collector; emitter grounded] **10**

(b)(ii) Implement an OR gate with AND and NOT gates. **5**

(b)(iii) Draw a positive logic OR gate with two diodes and explain its operation. **5**

(c)(i) Draw and explain the speed, torque and power-time curves for a typical electrical traction drive. Differentiate clearly between dynamic and regenerative braking. **10**

(c)(ii) A 3-phase, 400 V, six-pole, 50 Hz induction motor with parameters R_s=R_r'=1 Ω, X_s=X_r'=2 Ω (referred to stator) is under regenerative braking action. Calculate (i) the maximum overhauling torque that it can hold and the range of speed for safe operation and (ii) the speed at which it will hold the overhauling load with torque of 160 N-m. **10**

(d)(i) List the differences between microwave transistors and transferred electron devices. **10**

(d)(ii) Explain the structure of IMPATT diode. **5**

(d)(iii) List the properties of S-parameters. **5**

6. (a)(i) Use Thevenin's theorem to replace the three-loop circuits of figure by a single-loop equivalent circuit in which the identity of R_L is preserved. **10**

(a)(ii) Find the value of R_L so that the maximum power is consumed in it.

[Figure: Three-loop ladder with a common bottom wire: on the left a 60 V battery (+ at top) between the bottom wire and the top-left corner; top wire: 60 Ω from the top-left corner to node A; 30 Ω from node A to the bottom wire; from node A along the top wire a 50 V battery (+ terminal towards the right) in series with R_L to node B; 60 Ω from node B to the bottom wire; from node B a 40 Ω resistor in the top wire to the top-right corner; a 100 V battery (+ at top) between the top-right corner and the bottom wire] **10**

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	(b)(i)	Explain principle of super-heterodyning. List the advantages of super-heterodyne receiver over TRF receiver.	**10**
	(b)(ii)	Explain PLL FM demodulator	**10**
	(c)(i)	A certain microstrip line has the following parameters: ε_r=5.23, h = 8 mils, t = 2.8 mils, W = 10 mils. Calculate the characteristic impedance Z_0 of the line.	**10**
	(c)(ii)	Compare linear broadside arrays having uniform, binomial and Dolph – Tchebyscheff distributions.	**10**
7.	**(a)(i)**	Draw the field lines and equipotential surface when a point charge is placed near an infinite grounded conducting plane.	**10**
	(a)(ii)	Derive the expression for the force between the point charge and the conductor with the help of the above concept.	**5**
	(a)(iii)	Explain the cause of polarisation in a dielectric.	**5**
	(b)(i)	Explain the difference between coherent and non coherent detection of ON/OFF keying signals.	**10**
	(b)(ii)	State the Carson's rule, Given that the peak deviation is 75 kHz, determine, using Carson's rule, the bandwidths required for sinusoidal FM indexes of 0.25, 2.4, 5.5 and 7.	**10**
	(c)	Show that the radiation resistance of a small loop antenna is 31200 $(A/\lambda^2)^2$ ohm.	**20**
8.	**(a)(i)**	Explain with the help of neat diagram, the operation of a Schmitt trigger employing OP-AMP.	**10**
	(a)(ii)	With OP-AMP draw a circuit of a unity gain amplifier having no phase shift and give its one practical application.	**5**
	(a)(iii)	Draw the circuit of a two input adder with OP-AMP and explain its operation.	**5**
	(b)(i)	'Transformer is a constant-flux machine'. Justify.	**10**
	(b)(ii)	Explain logically why primary current increases when secondary side is loaded.	**5**
	(b)(iii)	Derive a condition for maximum efficiency of a transformer	**5**
	(c)	An ideal chopper operating with a chopping period of 2 m sec is supplying a load of 5 Ω resistance with inductance of 10 mHenry, from a battery of 100 volts. Assume the shunt diode to provide perfect commutation. Determine the load current waveform for the ratio $T_{OFF/ON}$=1/4 and average value of load voltage.	**20**

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