Civil Services (Main) Examination, 2013

ELECTRICAL ENGINEERING

(Paper I)

Time Allowed : Three Hours **Maximum Marks : 250**

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.
Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

SECTION 'A'

1. (a) Using Δ-Y substitution, determine the resistance between *a* and *d*, in Fig. 1.

[Figure: Fig. 1 – Bridge (diamond) network with nodes *a* (top), *b* (left), *c* (right), *d* (bottom): 2 Ω between *a* and *b*; 2 Ω between *a* and *c*; 1 Ω between *b* and *c* (horizontal diagonal); 2 Ω between *b* and *d*; 1 Ω between *c* and *d*.] **10**

(b) Figure 2 shows a square wave that is described through the range from 0 to π by $f(t)=2$, and through the range from π to 2π by $f(t)=0$. Find its Fourier components in the exponential series.

[Figure: Fig. 2 – Periodic square wave $f(t)$ plotted against $\omega_1 t$: value +2 from 0 to π and from 2π to 3π (and up to −π on the left), zero from −π to 0 and from π to 2π; axis marks −π, 0, π, 2π; amplitude marked +2.] **10**

(c) A conductor is charged by repeated contacts with a metal plate which, after each contact, is recharged to a quantity of charge *Q* by connecting it to a constant voltage source. If *q* is the charge of the conductor after the first operation, show that the ultimate charge on the conductor is $Q \cdot q/(Q-q)$. **10**

(d) Design an amplifier with a gain of +5 using one OP-AMP. Choose R_i=10 kΩ. **10**

(e)(i) Write the Maxwell's equations including the continuity equation in vector form for time-varying fields in general medium naming each of them. **5**

(e)(ii) Define the following parameters for an OP-AMP: Input offset voltage; Bias current; Slew rate; Output impedance; CMRR. **5**

2. (a) Consider the unbalanced Wheatstone bridge shown in Fig. 3: The internal resistance of the galvanometer is 1 ohm. Using Thevenin's theorem, determine the galvanometer current.

[Figure: Fig. 3 – Wheatstone bridge with nodes *a* (left), *c* (top), *b* (right), *d* (bottom): 100 Ω between *a* and *c*; 110 Ω between *c* and *b*; 100 Ω between *a* and *d*; 90 Ω between *d* and *b*; galvanometer G between *a* and *b*. Source *E* = 10 V (arrow pointing up, i.e. + toward the top) connected by the outer wires between *c* (top) and *d* (bottom).] **20**

(b) Determine the current *I* in Fig. 4 using the ladder method.

[Figure: Fig. 4 – Ladder network. Source V_g = 10 V (arrow up, + at top) on the left; top wire from the source through 2 Ω to node *a*; bottom wire from the source directly to node *a*′. 200 Ω between *a* and *a*′. Top series 1 Ω from *a* to *b*; bottom series 1 Ω from *a*′ to *b*′. 50 Ω between *b* and *b*′. Top series 2 Ω from *b* to *c*; bottom wire *b*′ to *c*′ (no element). 100 Ω between *c* and *c*′. From *c* a series 1 Ω along the top, then down through 10 Ω (current *I* downward) to the bottom wire at *c*′.] **20**

(c) In Fig. 5, capacitor C_1 is initially charged at 100 V and the other two capacitors are initially uncharged. The switch *S* is closed at time *t*=0. Find the current flowing through **10**

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the resistor as a function of time.

[Figure: Fig. 5 – C_1 = 1 μF (left), C_2 = 1 μF (middle) and C_3 = 2 μF (right), each between the top wire and a common bottom wire. Switch S in the top wire between C_1 and C_2; resistor R = 500 Ω in the top wire between C_2 and C_3.]

3. (a) Plane monochromatic waves are propagated parallel to the z-axis in both positive and negative directions. At the origin, the field strengths are given by

$$E_x = A\cos(\omega t \pm kz) \quad E_y = 0$$

$$H_x = 0 \quad H_y = B\cos(\omega t \pm kz)$$

Calculate the mean intensity of the radiation in each of the two directions in terms of A, B and the constants of the medium. **20**

(b) Show that the energy stored in a plane electromagnetic wave is equally divided between the electric and magnetic fields. **20**

(c) A lossless transmission line with air dielectric is 12 m long. What is the line length in wavelengths and what is the value of the phase constant β at 15 MHz? **10**

4. (a) Using an OP-AMP, design a lossy integrator whose peak gain is 20 dB and the gain is 3 dB down from its peak when ω=10000 rad/sec. Use a capacitance of 0.01 μF. **20**

(b) Design a voltage regulator using 7805 IC to get a voltage output of 8 V. **10**

(c) Design a second-order low-pass Butterworth filter having a cutoff frequency of 1 kHz. Choose C=0.1 μF. The damping factor α is given to be 1.414. Choose R_i as 10 kΩ. **20**

SECTION 'B'

5. (a) Specify power supply voltage range, output logic 1 level voltage and output logic 0 level voltage for standard TTL gates. **10**

(b) Why are 'high power to size ratio machines' like mixer, hand drill, vacuum cleaner, etc., using DC universal motor? **10**

(c) Specify the type of core used in DC–DC converter and explain why iron core is not used in it. **10**

(d) How is good selectivity achieved in a superheterodyne receiver? **10**

(e) Draw a block diagram to implement logic $F=A\cdot B$ using a 4×1 multiplexer. **10**

6. (a) Determine the MSP form of the switching function

$$F(uvwxyz)=\Sigma(0,1,4\text{–}6,11,14\text{–}17,20\text{–}22,30,32,33,36,37,48,49,52,53,59,63)$$

using 6-variable Karnaugh map. **20**

(b) A sequential machine produces an output of 1 only when exactly two 0's are followed by a 1 or exactly two 1's are followed by a 0. Determine the reduced state table of the machine. **20**

(c) Assuming that logic 0 is available, show that the INCLUSION gate is a universal building block. **10**

7. (a) A single-phase transformer of turns ratio 3 : 1 is connected to 110 V AC mains. It draws a primary current of 1 A at unity p.f. when delivering power to a load with an efficiency of 85%. If the no-load current of the transformer is 0.43 A, determine the p.f. at no load. **20**

(b) Draw the circuit diagram of SCR-based control circuit for full-range speed control of a shunt DC motor using two SCRs to run from single-phase AC mains. **20**

(c) What is the effect of gate capacitance of MOSFET in driving circuit when it is used in high-frequency power switching applications like sine wave inverter or DC–DC converter? **10**

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8. **(a)** A certain FM signal is represented by $V(t)=10\sin(10^8 t+15\sin 2000t)$ volts, where t is in seconds. Find the parameters of the FM wave. **20**

(b) Show that the Wiener-Hopf filter is practical only when the input SNR is small. **20**

(c) Explain why signal to noise ratio is better in FM receiver as compared to AM. Draw suitable diagrams in support of your explanation. **10**

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