ELECTRICAL ENGINEERING

Paper—I

Time : Three Hours

Full Marks : 300

*Candidates should attempt Question No. **1** from Section-A and Question No. **5** from Section-B which are compulsory, and any **THREE** of the remaining questions, selecting at least **ONE** from each Section.*

All questions carry equal marks.

SECTION—A

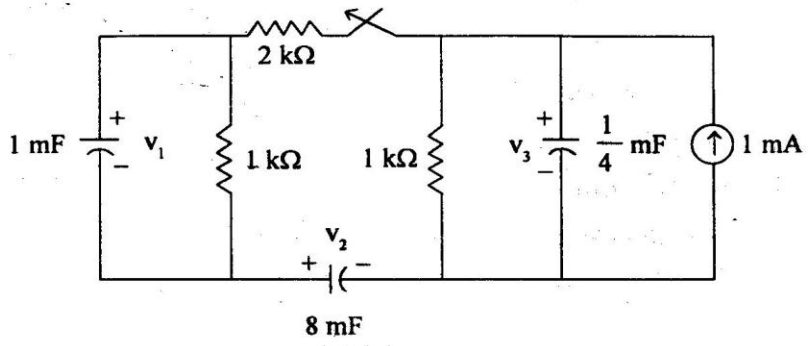
1. Answer any **THREE** of the following :—

   (a) Find the inverse Laplace transforms of (i) and (ii) :

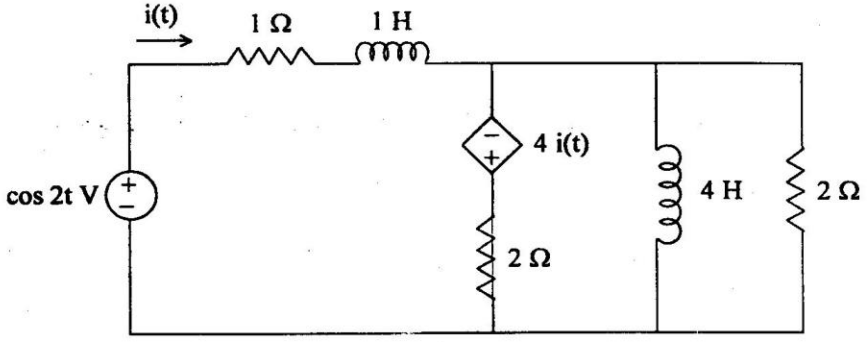
   (i) $\dfrac{3s^2+6}{s^2[(s+1)^2+16]}$ 6

   (ii) $\dfrac{1}{s^2[(s+1)^2+16^2]^2}$ 6

(iii) Find v_1, v_2 and v_3 for $t > 0$. Assume the circuit is in dc steady state at time $t = 0^-$. 8



(b) (i) Find the poles of the circuit. Is this circuit stable ? 10



(ii) Find the difference in phase between βd and Kd for confocal and concentric resonators for the rectangular modes (0, 0), (0, 1), (1, 1), (1, 2) and (2, 1). 10

(c) (i) What is the difference between SCR and TRIAC ? 4

(ii) What is the turn-off characteristic of thyristors ? 4

(iii) What is a brushless dc motor ? 4

(iv) The junction capacitance of a thyristor is $C_{j2} = 20$ pF and can be assumed independent of off-state voltage.The limiting value of charging current to turn on the thyristor is 15 mA. If a capacitor of 0·01 μF is connected across the thyristor, determine the critical value of $\frac{dv}{dt}$. 8

(d) (i) Develop the phasor diagram of a single phase transformer under lagging power factor load. 8

(ii) Draw the speed-torque characteristics of d.c. shunt, series and compound motors in one figure and compare them. Which characteristics is more suitable for traction purposes and why ? 4

(iii) An alternator has a synchronous reactance of 20% and negligible resistance. Calculate its voltage regulation when working at full load (a) 0·8 p.f. lag, and (b) 0·8 p.f. lead. 8

2. (a) (i) A single-phase full bridge inverter, which uses a uniform PWM with pulses per half cycle, has a load of R = 5 Ω, L = 15 mH, and C = 25 μF. The dc input voltage is V_s = 220 V. Express the instantaneous load current $i_o(t)$ in a Fourier series for M = 0·8, and f_0 = 60 Hz. 10

(ii) The speed of a 20-hp, 300 V, 1800 rpm separately excited dc motor is controlled by a three phase full-converter drive. The field current is also controlled by a three phase full converter and is set to the maximum possible value. The ac input is three phase, Y connected, 208 V, 60 Hz. The armature resistance is R_a = 0·35 Ω, the field resistance is R_f = 250 Ω, and the motor voltage constant is K_v = 1·15 V/A rad/s.

The armature and field currents are continuous and ripple free. The viscous friction and no-load losses are negligible.

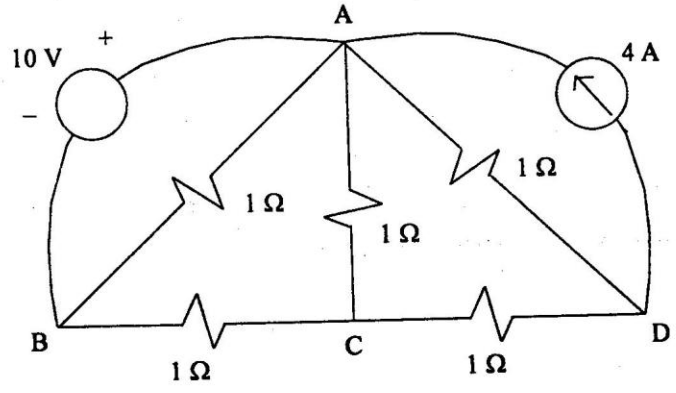
Determine (a) the delay angle of the armature converter α_a, if the motor supplies the rated power at rated speed (b) the no-load speed if the delay angles are the same as in (a) and the armature current at no-load is

10% of the rated value, and (c) the speed regulation. 10

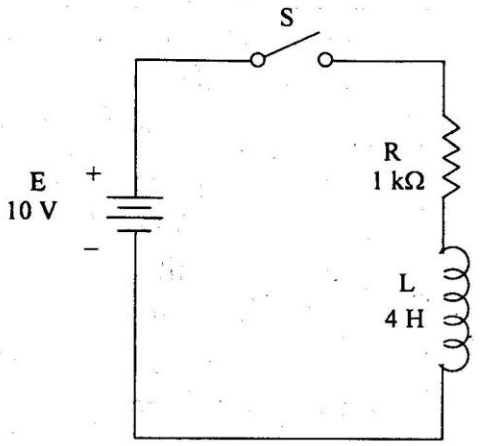
(b) (i) Analyze a TE surface wave over a plane with no variations in y and show that a capacitive reactance is necessary to produce an exponential decay with x. 10

(ii) A rectangular waveguide of inside dimensions 4 cm by 2 cm is to propagate a TE_{10} mode of frequency 5000 MC/sec. A dielectric of constant ε_r = 3 fills the guide for z > 0, with air dielectric for z < 0. Assuming the dielectric-filled part to be matched, find the reflection coefficient at z = 0 and the standing wave ratio in the air filled part. 10

(c) (i) Find out currents in all branches of the fig. shown below by current variables method. 8



(ii) Write a program to transient analyze the LR circuit to determine V_L and I_L and to plot a graph of these quantities. 12



3. (a) (i) A universal f.h.p. series motor has a resistance of 30 Ω and total inductance of 0·5 H.

When connected to a 250 V d.c. supply and loaded to take 0·8 A, it runs at 2,000 rpm. Estimate the speed and power factor when connected to a 250 V, a.c. supply and loaded to the same current. 10

(ii) A 420 V, 6 pole, 50 Hz star connected induction motor has stator impedance of 0·07 + j0·30 Ω and standstill rotor impedance

referred to stator is 0·08 + j0·37 Ω. The magnetizing current is neglected. Determine :

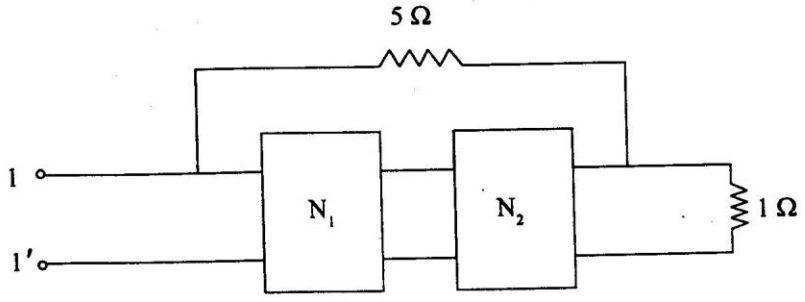
(a) the maximum internal power developed and the corresponding slip, and

(b) the maximum internal torque and the slip at which it occurs. 10

(b) (i) Determine the driving point impedance of the network shown in Fig. as seen from terminals 11' given that N_1 and N_2 are identical.

Each of the two parts is characterised by

$$Z_{oc} = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}. \quad 10$$



(ii) Design a composite low-pass filter (T-section) to be terminated in 600 Ω resistance. It must have a cut-off frequency of 2 kHz

with infinite attenuation at 2·1 kHz. The half-section terminations are to be provided for m = 0·6. 10

(c) (i) A three phase four wire ABC system has the reference line voltage $V_{BC} = 230\angle 0°$ V. A wye connected load with $Z_A = 5\angle 0°\ \Omega$, $Z_B = 10\angle 30°\ \Omega$ and $Z_C = 5\angle -30°\ \Omega$ is fed by the system. Determine the line and the neutral currents. 8

(ii) Show that the power flow in the uniform plane wave equals the product of the average energy density and the group velocity v of the wave. 8

(iii) Find the Fourier transform of the square pulse

$$x(t) = \begin{cases} 1 & \text{for } -T < t < T \\ 0 & \text{otherwise} \end{cases}$$ 4

4. (a) (i) Obtain the First Foster form and Second Foster form of the following function

$$Z(s) = \frac{s^2 + 6s + 8}{s^2 + 4s + 3}.$$ 10

(ii) Synthesize the driving point function

$$Z(s) = \frac{s^4 + 2s^3 + 3s^2 + 5s + 1}{s^4 + s^3 + 5s^2 + s + 4}.$$ 10

(b) Draw the complexor diagram and find the applied voltage and power factor of a 25 c/s, 6 pole compensated series motor running at 1,000 rpm and taking 60 A, the motor having the following particulars :—

Useful flux per pole at 60 A = 0·0075 wb

Total stator flux per pole at 60 A = 0·0078 wb

Wave connected armature with 848 conductors and 2 turns per coil.

Field winding = 15 turns per poles, all poles being in series.

Total resistance = 0·31 Ω

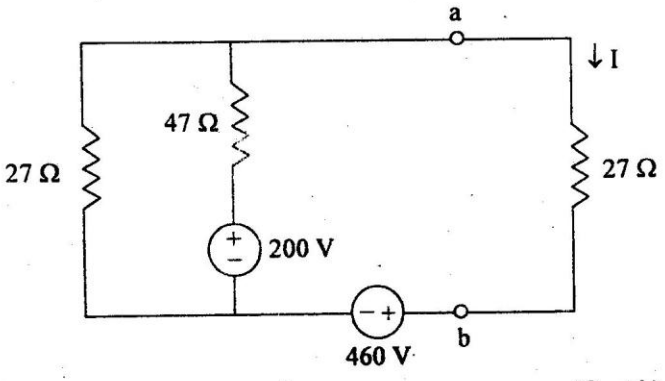
Armature leakage reactance = 0·53 Ω

Friction, windage and iron loss component of current = 5 A.

Component of current supplying loss in short circuited coils = 8A.

Find also the e.m.f. in the short circuited coil. 20

(c) (i) Find the Thevenin equivalent and Norton equivalent of the following circuit : 6+6



(ii) A series resonant circuit has Band width = 200 Hz and Q-factor = 100. It uses a capacitor of 500 μF. Calculate the other constants of the circuit.

If an ac voltage of 1 V rms is connected to the circuit, what will be the voltage across the inductor, capacitor and resistor at resonance. 8

SECTION—B

5. Answer any **THREE** of the following :—

(a) (i) In the transistor amplifier shown in Fig. 1. R = 10 k Ohm, R = 30 k Ohm and V_{cc} = 20 V. The values of R1 and R2 are so as to fix the operating point at 10 V, 1·5 mA. Draw the DC and AC load lines. Assume R_e is negligible. 5

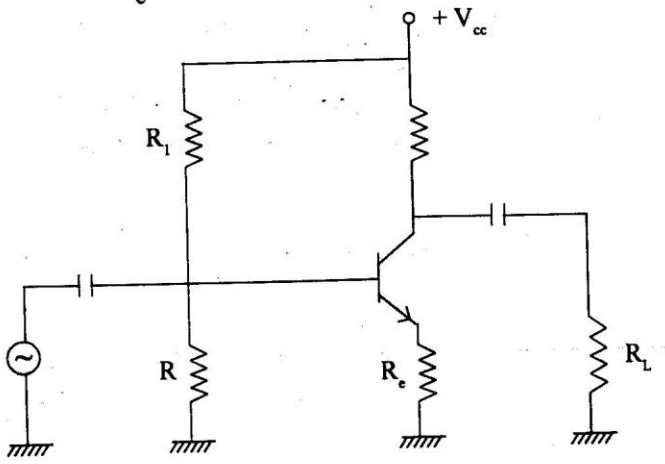


Fig. 1

(ii) In a full wave rectifier, the load resistance is 3k Ohm. Each diode has an ideal characteristic having slope corresponding to a resistance of 400 ohm. Voltage applied to the circuit is 220 sin (50 t). Find :

(i) peak value of current

(ii) dc value of current

(iii) r.m.s. value of current

(iv) rectifier efficiency

(v) ripple factor. 10

(iii) Design a diode clamper to restore a dc level of + 2V to an input signal of peak to peak value of 20V. Assume the drop across diode is 0·7V. 5

(b) (i) The hybrid parameters for a transistor used in the CE configuration are h_{ie} = 1·25 k Ohm, $h_{re} = 10^{-4}$, h_{fe} = 60, h_{oe} = 100 μ℧. The transistor has a load resistance of 1 k Ohm in collector lead and is supplied from a signal source of resistance 600 Ohm. Calculate

(a) the input resistance

(b) output resistance

(c) voltage gain

(d) current gain.

Derive the relations used. 10

(ii) Calculate voltage gain, input resistance and output resistance in a CE amplifier with current shunt negative feedback. Draw the circuit diagram and its equivalent circuit. 10

(c) (i) Design a voltage divider bias circuit in which $V_{cc} = 20$ V, $V_Q = 10$ V and $I_Q = 1$ mA. The circuit should perform satisfactorily using silicon transistor whose values of β range from 50 to 200. 10

(ii) The transistor shown in Fig. 2 has h_{ib} = 15 Ohm, $h_{rb} = 4\times10^{-5}$, $h_{fe} = -0{\cdot}992$ and $h_{ob} = 4\times10^{-7}$ S. Find :

(a) r_{in},

(b) r_{in}(stage),

(c) V_L/V_S,

(d) r_o,

(e) r_o (stage). 10

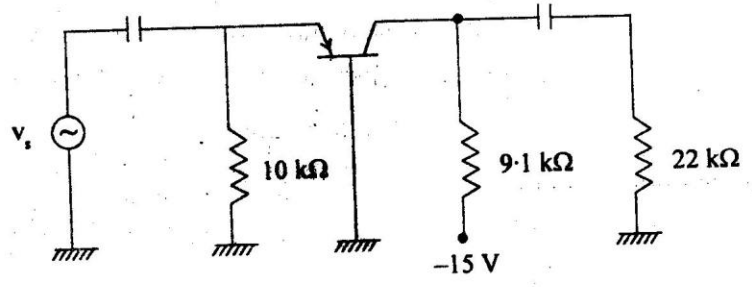


Fig. 2

(d) (i) Describe carrier acquisition in DSB-SC system. 10

(ii) Determine the bandwidth of commercial FM transmission assuming frequency deviation Δf = 75 kHz and bandwidth of modulating signal m(t), w = 15 kHz. 10

6. (a) (i) A class B push pull amplifier has a supply voltage of 30 V, a biasing current of 1 mA and a quiescent collector current of 1 mA. If the amplifier has the load line of Fig. 3, what are the no signal current drain, full signal current drain and the stage efficiency ? 10

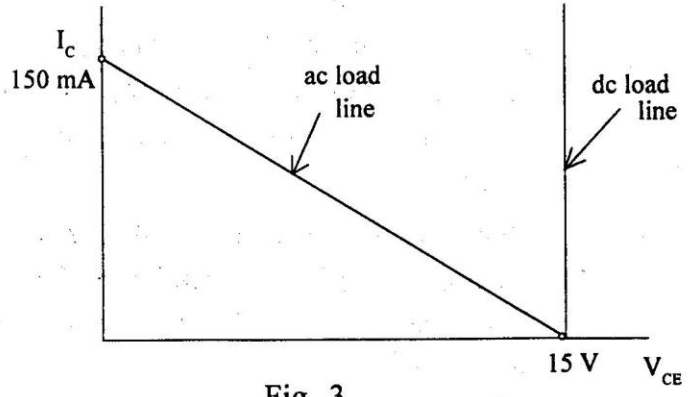


Fig. 3

(ii) In Fig. 4 what is the closed loop voltage gain in the midband of the feedback ? The small signal bandwidth ? The largest

output peak value with the slew rate distortion ? 10

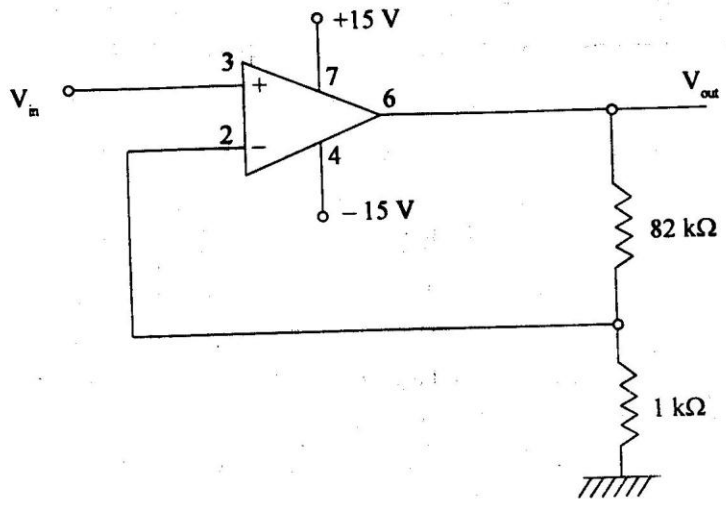


Fig. 4

(b) (i) Design a synchronous divide by six UP counter arranged so that any transition from unused states end at the first used states. 10

(ii) Draw the circuit diagram in NAND gate form for a circuit with three inputs A, B and C and three outputs X, Y and Z. The outputs are given by

$$X = A \cdot B \cdot \overline{C} + A \cdot \overline{B} \cdot C$$

$$Y = \overline{A} \cdot B + A \cdot \overline{B} \cdot C$$

$$Z = \overline{A} \cdot B + B \cdot \overline{C}$$ 10

(c) (i) A 6-bit R-2R ladder D/A converter has a reference voltage of 6·5 V. It meets standard linearity. Determine

(a) the resolution in per cent and volts

(b) the full scale voltage,

(c) the output for 011000,

(d) the range in output for 011000. 10

(ii) With a block diagram, explain the operation of Dual slope A/D converter. 10

7. (a) (i) A long distance microwave link consists of a chain of repeaters located at 50 km intervals. What must be the minimum height of transmitting and receiving antennas above ground level so that line of sight condition is ensured. The antennas are identical to each other. 5

(ii) Explain the atmospheric effects on space wave propagation. 10

(iii) A radio station has an antenna height of 100 m and transmitting frequency of 1·25 MHz. The transmitter and antenna current is 9A. Calculate the voltage received by a receiver antenna placed at a distance of 60 km with a height of 3·5 m. 5

(b) (i) Calculate the radiation resistance of a $\lambda/16$ wire dipole in free space. Also find the antenna efficiency if the loss resistance is 1·05 ohms. 5

(ii) A 64 m diameter paraboloid reflector is fed by a non-directional antenna at 1450 MHz. Calculate :

(a) the bandwidth between half-power points and between nulls and

(b) the power gain with respect to a half wave dipole assuming uniform illumination. 10

(iii) Explain artificial dielectrics and why they are preferred for lens antennas. 5

(c) (i) Explain with neat sketches the principle of operation of an adopted calorimetric method to measure the Microwave power. 10

(ii) Explain in detail how the insertion loss in any section on a microwave system can be measured. 10

8. (a) (i) Derive an expression for modulation index of amplitude modulated wave modulated by several sinusoidal signals. 10

(ii) The antenna current of an AM broadcast transmitter modulated to depth of 65% by an audio sine wave is 20 amperes. It increases to 22 amperes as a result of simultaneous modulation by another audio sine wave. Find the modulation index due to this second sine wave. 10

(b) (i) A 100 MHz carrier wave has a peak voltage of 5 volts. The carrier frequency is modulated by a sinusoidal signal or wave form of frequency 2 kHz such that the frequency deviation Δf is 60 kHz. The modulated waveform passes through zero and is increasing at $t = 0$. Find the expression for the modulated carrier waveform. 10

(ii) Explain the Reactance modulator method of FM generation and show that the equivalent capacitance is dependant on the FET device transconductance. 10

(c) (i) The PDF of a random variable X is given by $f(x) = a\ e^{-b|x|}$. Determine the relationship between a and b, CDF and probability that the output lies between –1 and 2. Assume $-\infty < x < \infty$ and $a = 3$. 10

(ii) Explain why the Gaussian distribution is widely used. 10