

# ELECTRONICS AND TELECOMMUNICATION 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.*

*Questions No. **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.*

*Diagrams / figures, wherever required, shall be drawn in the space provided for answering the question itself.*

*Unless otherwise mentioned, symbols and notations have their usual standard meanings.*

*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 (QCA) Booklet must be clearly struck off.*

*Answers must be written in **ENGLISH** only.*

### **Values of constants which may be required :**

*Electron charge* =  $-1.6 \times 10^{-19}$  Coulomb

*Free space permeability* =  $4\pi \times 10^{-7}$  Henry/m

*Free space permittivity* =  $(1/36\pi) \times 10^{-9}$  Farad/m

*Velocity of light in free space* =  $3 \times 10^8$  m/s

*Boltzmann constant* =  $1.38 \times 10^{-23}$  J/K

*Planck's constant* =  $6.626 \times 10^{-34}$  J-s

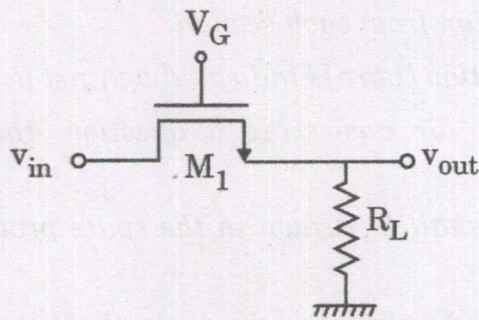
## SECTION A

- Q1. (a)** Consider an ideal pMOS capacitor of area  $100 \mu\text{m} \times 100 \mu\text{m}$  operated at  $T = 300 \text{ K}$ .  $\phi_M$  (work function for the metal) =  $5.2 \text{ eV}$ ,  $x_o$  (oxide thickness) =  $3 \text{ nm}$  and  $N_D = 10^{17}/\text{cm}^3$ . Calculate the flat band voltage  $V_{FB}$  and the threshold voltage  $V_{TP}$ . Assume  $E_{ox} = 3.43 \times 10^{-13} \text{ F/cm}$ ,  $V_T$  (thermal voltage) =  $0.026 \text{ V}$ ,  $n_i = 10^{10}/\text{cm}^3$ ,  $\chi_{Si}$  (electron affinity of Si) =  $4.05 \text{ eV}$ ,  $E_G = 1.12 \text{ eV}$  and  $E_{Si} = 10^{-12} \text{ F/cm}$ . 12

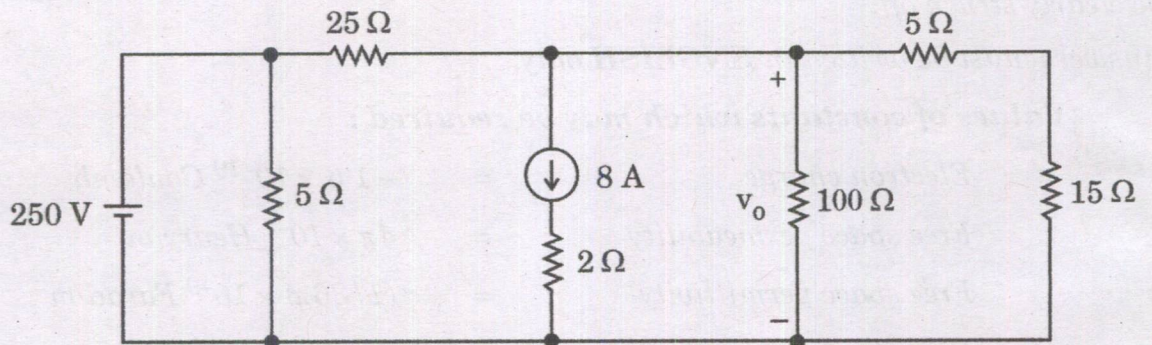
- (b) In the circuit shown in the figure below,  $M_1$  serves as an electronic switch. If  $v_{in}$  is very small, determine  $W/L$  such that circuit attenuates the signal by 5%.

Assume  $V_G = 1.8 \text{ V}$  and  $R_L = 100 \Omega$ .

$$\mu_n C_{ox} = 200 \frac{\mu\text{A}}{\text{V}^2} \text{ and } V_{TN} = 0.4 \text{ V.} \quad 12$$



- (c) Find the voltage  $v_o$  in the circuit shown in the figure using source transformation. Also, find the power developed by the  $250 \text{ V}$  voltage source. 12



- (d) An electrical load absorbs an average power of  $85 \text{ kW}$  at lagging power factor of  $0.85$ . If the load operates at  $240 \text{ V rms}$ , calculate the complex power and impedance of the load. 12

- (e) (i) Draw neat sketches of the edge and screw dislocations. Illustrate the Burger's vector on the sketches of dislocations. 6
- (ii) Calculate the line energy of dislocation in BCC iron if the shear modulus and lattice parameter of BCC iron are  $80.2 \text{ GN/m}^2$  and  $2.87 \text{ \AA}$ , respectively. 6

**Q2.** (a) A p-n junction solar cell is fabricated using silicon and has the following important parameters :

$$N_A = 3 \times 10^{18} /\text{cm}^3, N_D = 2 \times 10^{16} /\text{cm}^3$$

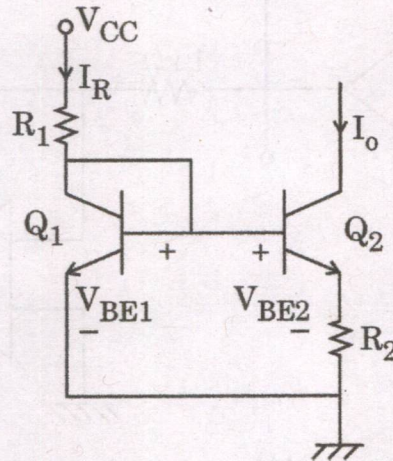
$$D_n = 25 \text{ cm}^2/\text{s}, D_p = 10 \text{ cm}^2/\text{s}$$

$$\tau_{n0} = 4 \times 10^{-7} \text{ s}, \tau_{p0} = 10^{-7} \text{ s}$$

The photocurrent density  $J_L = 20 \text{ mA/cm}^2$ . Calculate the open circuit voltage of the solar cell at  $T = 300 \text{ K}$ . Assume  $n_i = 1.5 \times 10^{10} /\text{cm}^3$ . 10

- (b) (i) What are the two functions of commutator in DC machines? 5
- (ii) Explain how the commutator keeps the armature mmf stationary in space, along the interpolar axis, even though the armature rotates. 15
- (c) (i) Explain why end-centred tetragonal geometry does not exist in Bravais crystal structures. 10
- (ii) Differentiate between different types of magnetic materials on the basis of magnetic dipoles and hysteresis loops. 10

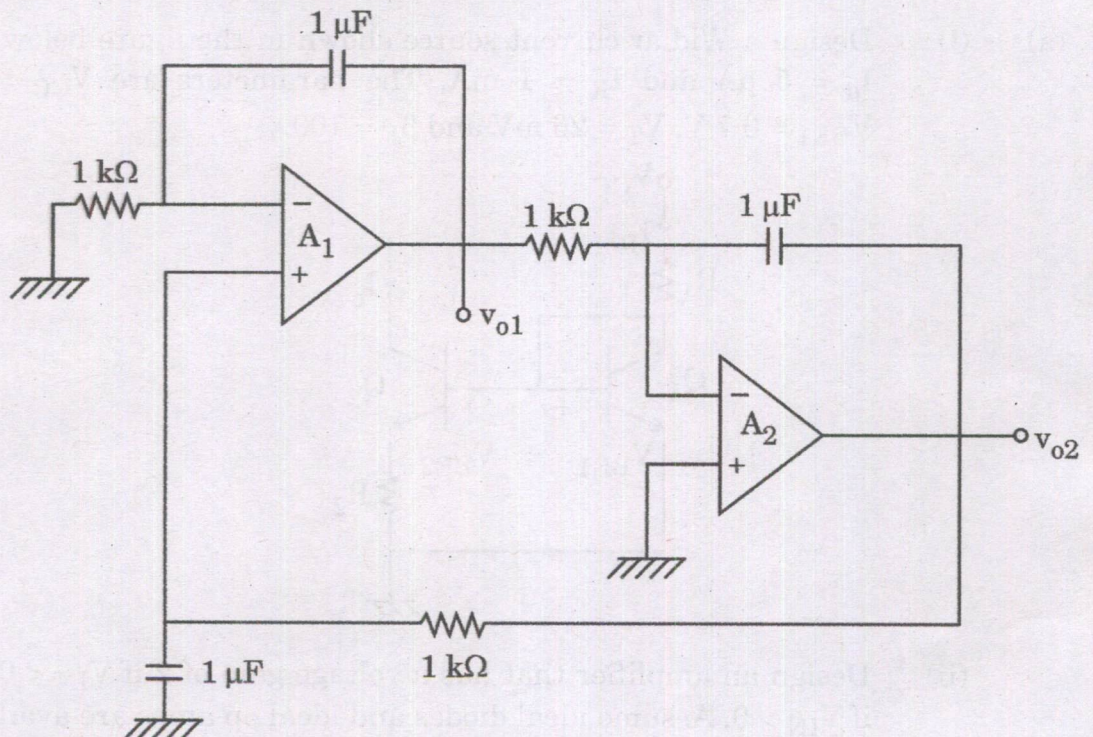
**Q3.** (a) (i) Design a Widlar current source shown in the figure below to give  $I_o = 5 \mu\text{A}$  and  $I_R = 1 \text{ mA}$ . The parameters are  $V_{CC} = 30 \text{ V}$ ,  $V_{BE1} = 0.7 \text{ V}$ ,  $V_T = 26 \text{ mV}$  and  $\beta_F = 100$ . 10



- (ii) Design an amplifier that has a voltage gain of 2 if  $V_{IN} < 0$  and 1, if  $V_{IN} > 0$ . Assume ideal diodes and ideal op amps are available. 10

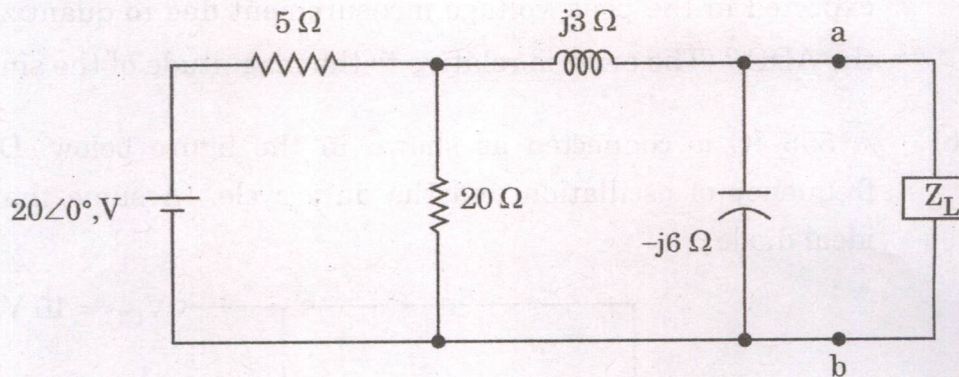
- (b) (i) Discuss the points of similarities between a transformer and induction machine. Explain, why an induction machine is called a generalized transformer. 10
- (ii) A 10 kVA/2500/250 V, single-phase transformer has the following parameters :
- Primary winding (h.v. side) : Resistance  $r_1 = 2.4 \Omega$   
 Leakage Reactance,  $x_1 = 6.00 \Omega$
- Secondary winding (l.v. side) : Resistance  $r_2 = 0.03 \Omega$   
 Leakage Reactance,  $x_2 = 0.07 \Omega$
- With primary supply voltage held constant at 2500 V, calculate the secondary terminal voltage, when the low voltage winding is connected to a load impedance of  $5 + j 3.5 \Omega$  and the transformer delivers its rated current at 0.8 p.f. lagging on the low voltage side. 10
- (c) (i) Discuss photoelectric effect and find out the number of photoelectrons emitted per unit time from a transmitter operated at a frequency of 800 kHz and 10 kW power. 10
- (ii) Define dielectric strength. Discuss different types of dielectric breakdowns in solids. 10

- Q4.** (a) For the circuit shown in the figure below, determine the frequency of oscillation  $f_o$  and overall voltage gain  $A_v$ . Also identify the type of oscillator. (Assume op amps are ideal) 20



- (b) (i) Determine the impedance  $Z_L$  that results in maximum average power transferred to  $Z_L$  for the circuit shown in the figure. Calculate the maximum average power transferred to the load impedance determined.

10



- (ii) What are the major factors that have led to the acceleration and development of solar and wind power ?

10

- (c) To produce a p-type semiconductor, the boron is doped in pure silicon. Doping is done through a  $B_2O_3$  vapour phase of a surface concentration equivalent to  $3.3 \times 10^{26}$  boron atoms/ $m^3$ . Calculate the time required to get a boron content of  $10^{23}$  atoms/ $m^3$  at a depth of  $2 \mu m$ . The doping temperature is  $1000^\circ C$  and  $D_B$  in Si at this temperature is  $4 \times 10^{-17} m^2/s$ .

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Given :  $\text{erf}(0.95) = 0.8209$

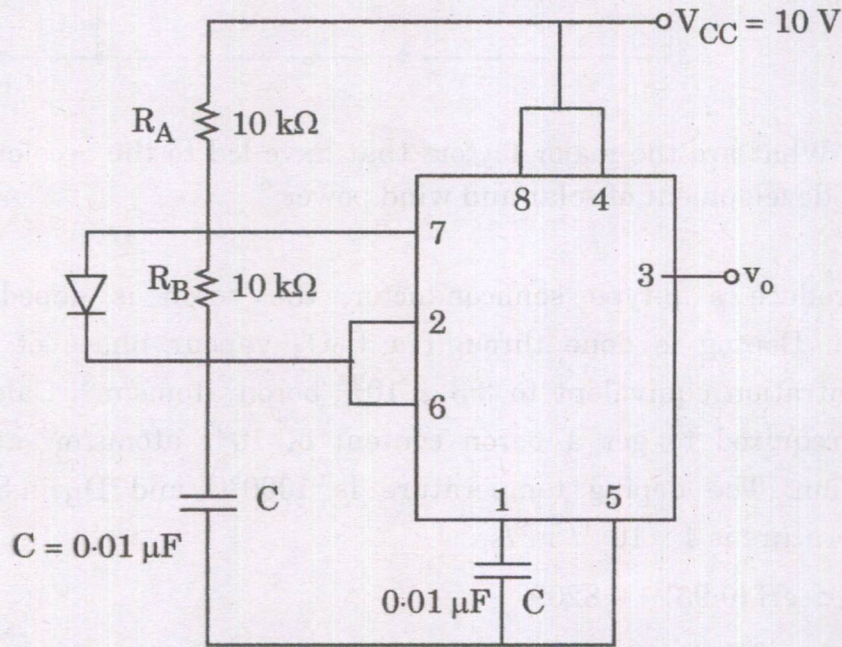
$\text{erf}(1.0) = 0.8427$

$\text{erf}(2.4) = 0.9993$

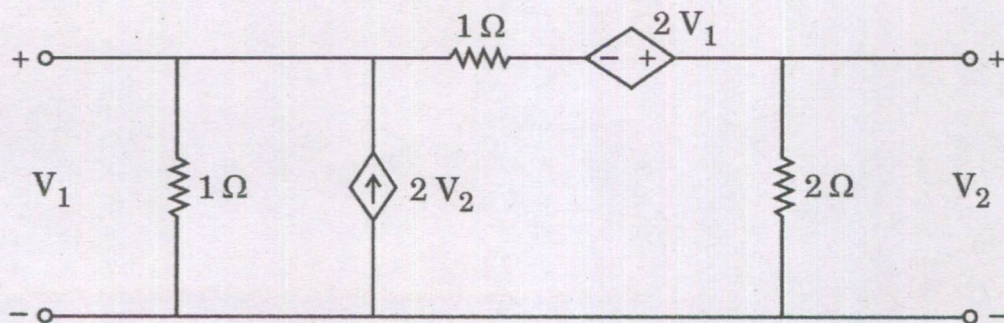
$\text{erf}(2.6) = 0.9998$

## SECTION B

- Q5.** (a) Assume an ideal 10 bit ADC with  $V_{REF} = 5\text{ V}$  is used to sample  $1V_{p-p}$  sinusoidal signal that has a  $2.5\text{ V}$  offset. What percent of error can be expected in the peak voltage measurement due to quantization effect of the ADC? (The error is relative to the magnitude of the sinusoid). 12
- (b) A 555 IC is connected as shown in the figure below. Determine the frequency of oscillation and the duty cycle. (Assume that diode is an ideal diode). 12

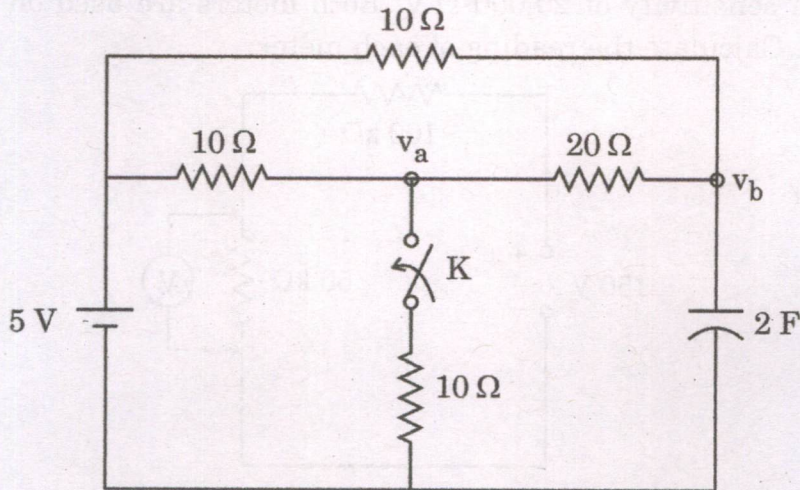


- (c) (i) The network of the figure contains both a dependent voltage source and a dependent current source. Determine the  $y$  and  $z$  parameters. 6



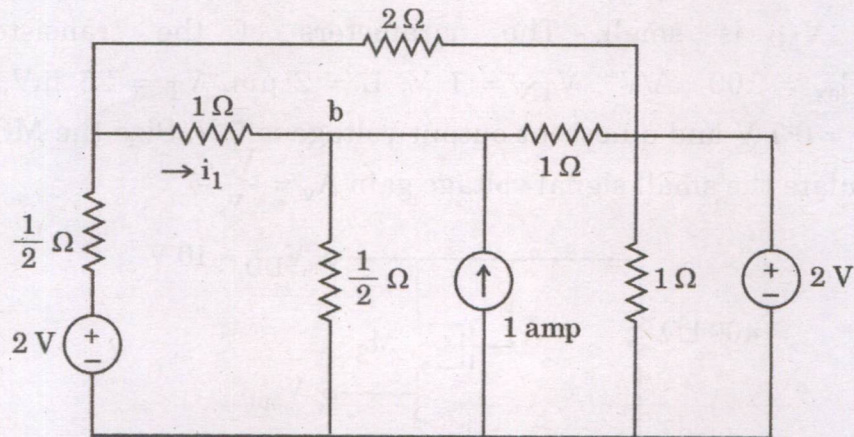
- (ii) In the figure shown, a network with a steady state is reached with switch K open. At  $t = 0$ , the switch is closed. For the element values given, determine the value of  $v_a(0^-)$  and  $v_a(0^+)$ .

6



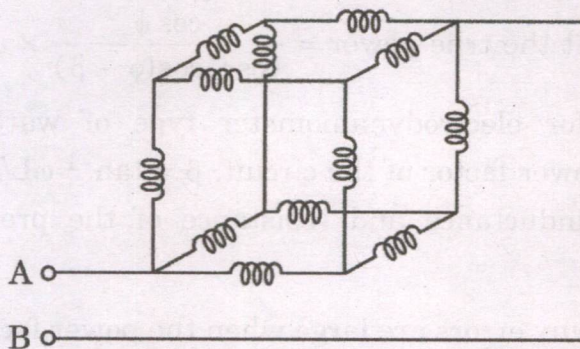
- (d) (i) For the figure shown, find  $i_1$ .

6

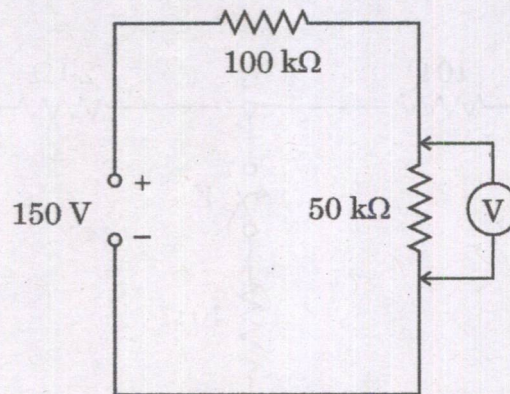


- (ii) The network of inductors in the figure below is composed of a 1 H inductor on each edge of a cube with the inductors connected to the vertices of the cube as shown. Find out the  $L_{\text{equivalent}}$  between the terminals A - B.

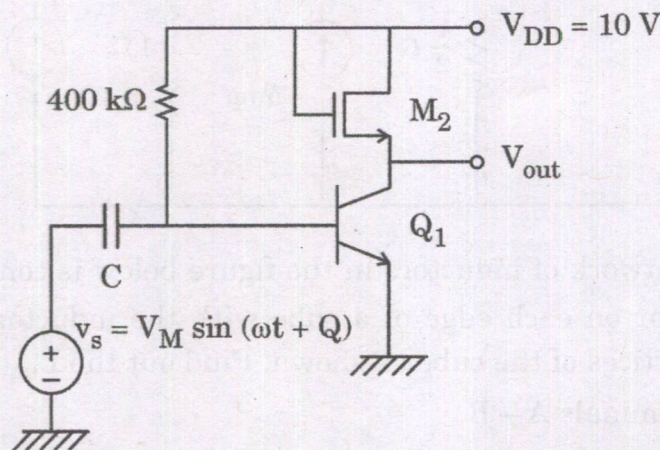
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- (e) It is desired to measure the voltage across the  $50\text{ k}\Omega$  resistor in the circuit shown in the figure. Two voltmeters are available for this measurement : Voltmeter 1 with sensitivity of  $1000\ \Omega/\text{V}$  and Voltmeter 2 with a sensitivity of  $20,000\ \Omega/\text{V}$ . Both meters are used on their  $50 - \text{V}$  range. Calculate the reading of each meter. 12



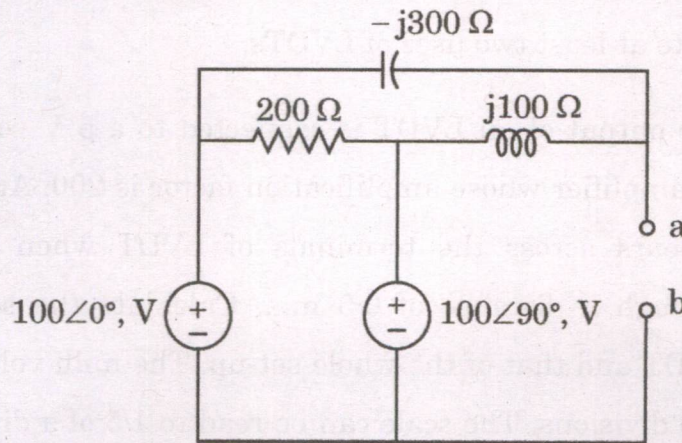
- Q6.** (a) For the circuit shown in the figure below, MOS and BJT are operating in saturation and active mode, respectively. The capacitor  $C$  is very large and  $V_M$  is small. The parameters of the transistors are :  $\mu_n C_{ox} = 100\ \mu\text{A}/\text{V}^2$ ,  $V_{TN} = 1\ \text{V}$ ,  $L = 2\ \mu\text{m}$ ,  $V_T = 25\ \text{mV}$ ,  $\beta_F = 100$ ,  $V_{BE} = 0.7\ \text{V}$  and quiescent output voltage is  $5\ \text{V}$ . Size the MOSFET and calculate the small signal voltage gain  $A_v = \frac{V_{ow}}{v_s}$  20



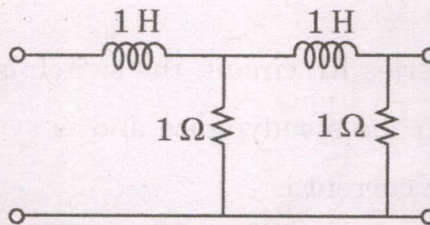
- (b) (i) Prove that the true power =  $\frac{\cos \phi}{\cos \phi \cdot \cos(\phi - \beta)}$   $\times$  actual watt meter reading for electro-dynamometer type of watt meters, where,  $\cos \phi =$  power factor of the circuit,  $\beta = \tan^{-1} \omega L/R$  where,  $L$  and  $R$  are the inductance and resistance of the pressure coil of the circuit. 10
- (ii) Explain why errors are large when the power factor is low. 10



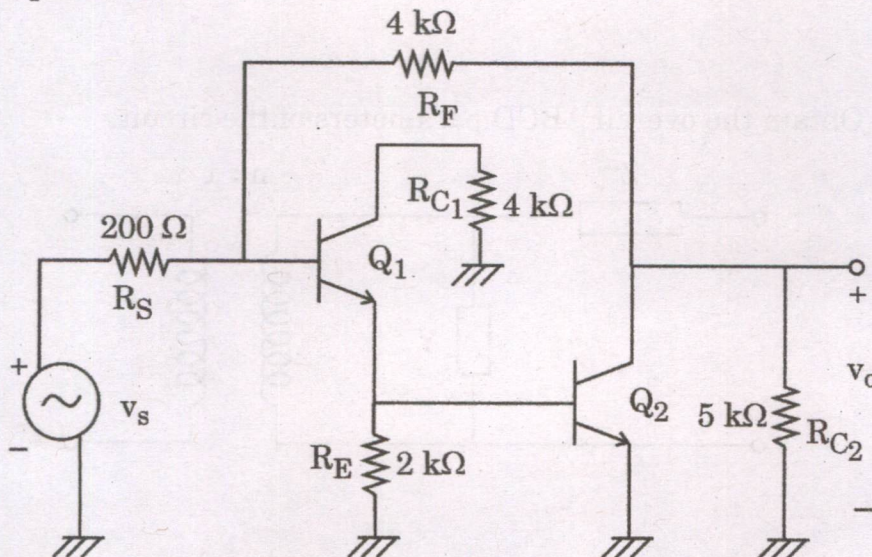
- (c) (i) Find the Thevenin's equivalent for the circuit at terminals a – b. 10



- (ii) For the ladder network determine the  $g$  parameters in the  $s$  domain. 10

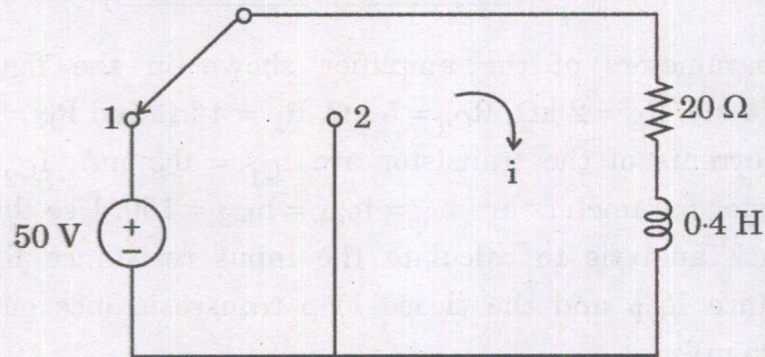


- Q7.** (a) The parameters of the amplifier shown in the figure below are  $R_{C1} = 4 \text{ k}\Omega$ ,  $R_E = 2 \text{ k}\Omega$ ,  $R_{C2} = 5 \text{ k}\Omega$ ,  $R_F = 4 \text{ k}\Omega$  and  $R_S = 200 \Omega$ . The DC bias currents of the transistor are  $I_{C1} = 0.5 \text{ mA}$ ,  $I_{C2} = 1 \text{ mA}$ . The transistor parameters are  $h_{fe} = h_{fe1} = h_{fe2} = 150$ . Use the techniques of feedback analysis to calculate the input resistance  $R_{IF}$ , the output resistance  $R_{OF}$  and the closed loop transresistance gain  $A_f$ . Assume  $V_T = 25 \text{ mV}$ . 20

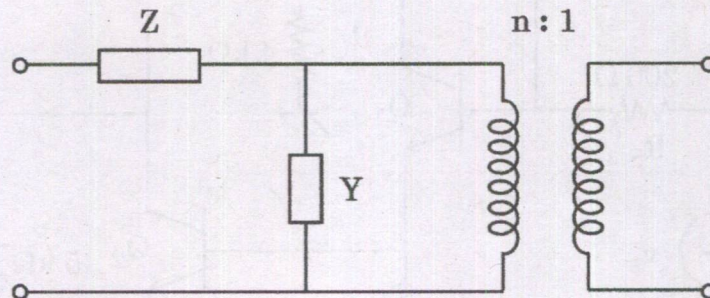


- (b) (i) Explain at least five advantages and disadvantages of LVDT. State at least two uses of LVDTs. 10
- (ii) The output of an LVDT is connected to a 5 V voltmeter through an amplifier whose amplification factor is 200. An output of 2 mV appears across the terminals of LVDT when the core moves through a distance of 0.5 mm. Calculate the sensitivity of the LVDT and that of the whole set-up. The milli voltmeter scale has 100 divisions. The scale can be read to  $\frac{1}{5}$  of a division. Calculate the resolution of the instrument in mm. 10

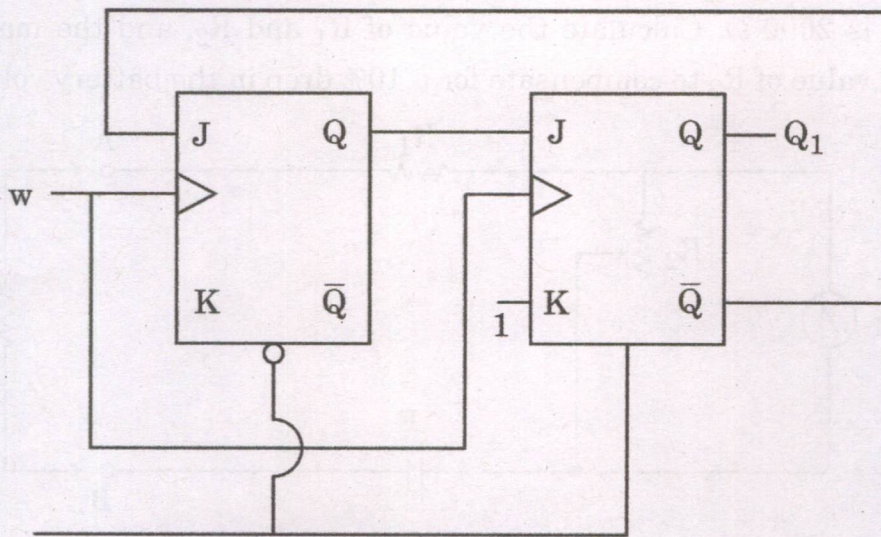
- (c) (i) In the series RL circuit, the switch is in position 1 long enough to establish the steady state and is switched to position 2 at  $t = 0$ . Find the current  $i$ . 10



- (ii) Obtain the overall ABCD parameters of the circuit. 10

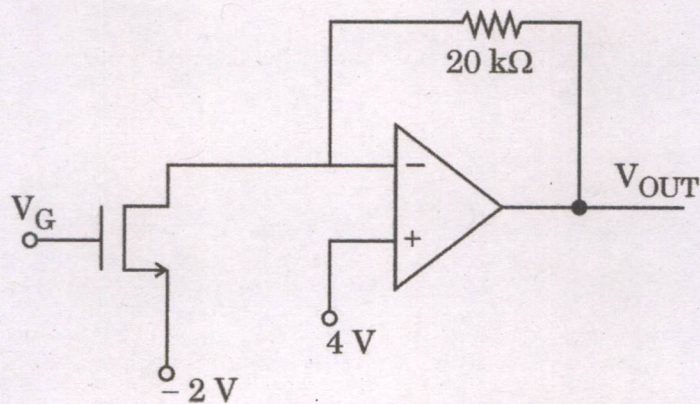


- Q8. (a) (i) Determine the functional behaviour of the circuit. Assume that input  $w$  is driven by a square wave signal. 10



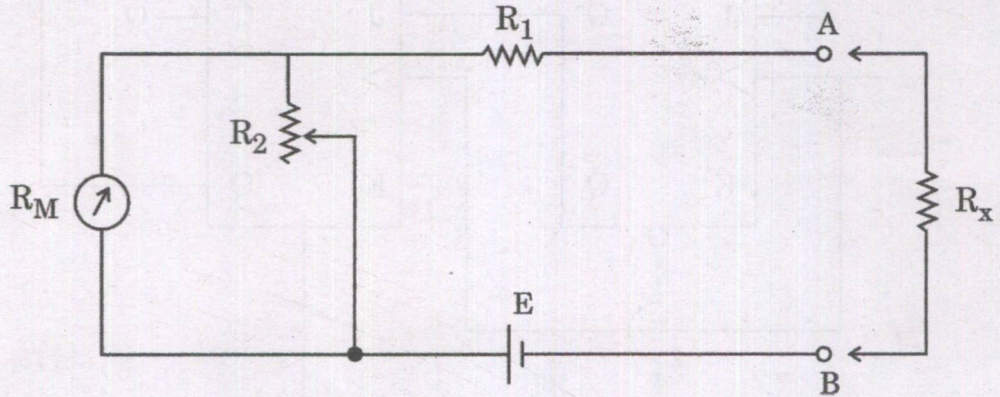
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- (ii) In the circuit shown in the figure below, the gate voltage  $V_G$  is very small. Assume op amp is an ideal op amp,  $V_{TN} = 1\text{ V}$  and  $\frac{\mu_n C_{ox} w}{L} = \frac{200\ \mu\text{A}}{\text{V}^2}$ . Calculate output voltage. 10



- (b) (i) Describe the construction and working of a shunt type ohmmeter. Write down its design equations. 10

- (ii) The ohmmeter shown in the figure uses a  $100\ \Omega$  basic movement requiring a full-scale current of  $1\ \text{mA}$ . The internal battery voltage is  $3\ \text{V}$ . The desired scale marking for half-scale deflection is  $2000\ \Omega$ . Calculate the value of  $R_1$  and  $R_2$ , and the maximum value of  $R_2$  to compensate for a  $10\%$  drop in the battery voltage. 10



- (c) A series resonant network consists of a  $50\ \Omega$  resistor, a  $4\ \text{mH}$  inductor and a  $0.1\ \mu\text{F}$  capacitor. Calculate values for (a)  $\omega_0$ , (b)  $f_0$ , (c)  $Q_0$ , (d)  $\text{BW}$ , (e)  $\omega_1$ , (f)  $\omega_2$ , (g)  $Z_{\text{in}}$  at  $45\ \text{k rad/sec}$ , and (h), the ratio of magnitude of the capacitor impedance to resistor impedance at  $45\ \text{k rad/sec}$ . 20