MADE EASY
Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-9 : Control Systems + Analog Circuits [All topics]

Advanced Electronics-2 + Electronic Measurements and Instrumentation-2 [Part Syllabus]

Name : .....

Roll No : | | | | | | | | | | | | |

Test Centres			Student's Signature
Delhi ☐	Bhopal ☐	Jaipur ☐	
Pune ☐	Hyderabad ☐		

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

Signature of Evaluator ..... Cross Checked by .....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

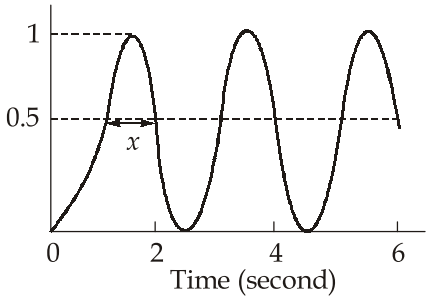
Section A : Control Systems + Analog Circuits

Q.1 (a) A system is represented by the following set of equations. Construct the signal flow graph from the given equations and find the closed-loop transfer function of the system.

$x = x_1 + t_3 u, \quad \dot{x}_1 = -q_1 x_1 + x_2 + t_2 u, \quad \dot{x}_2 = -q_2 x_1 + t_1 u$

[12 marks]

Q.1 (b) The unit step response of a unity feedback system exhibits sustained oscillations as shown in the figure below. The open-loop transfer function of the system is $G(s) = \dfrac{K}{(s+1)(s+4)(s+a)}$. The time x in the figure is 1.0471 second. Determine the values of K and a.

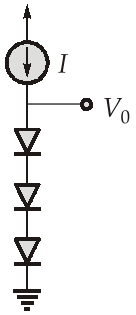


[12 marks]

Q.1 (c) The forward path transfer function of a negative unity feedback system is given by $G(s) = \frac{K}{s(s+T)}$. Determine the values of K and T such that all the roots of characteristic equation are in the left-half plane of the vertical line passing through $s = -a$.

[12 marks]

Q.1 (d) The circuit in the figure utilizes three identical diodes having $\eta = 1$ and $I_S = 10^{-14}$ A. Find the value of the current I required to obtain an output voltage $V_0 = 2$ V. If a current of 1 mA is drawn away from the output terminals by a load, what is the change in output voltage? (Assume $V_T = 25$ mV)



[12 marks]

Q.1 (e) A differentiator utilizes an ideal op-amp, a 10 kΩ resistor and a 0.01 μF capacitor.

(i) What is the frequency f_0 (in Hz) at which the input and output sine-wave signals have equal magnitude?

(ii) What is the output signal for a 1 volt peak to peak sine wave input with frequency equal to $10f_0$?

[6 + 6 marks]

Q.2 (a) The closed-loop frequency response $|M(j\omega)|$ versus frequency of a second-order prototype system is shown in figure (a) and the unit response of the system is shown in figure (b).

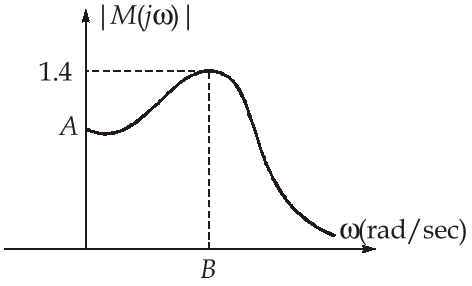


figure (a)

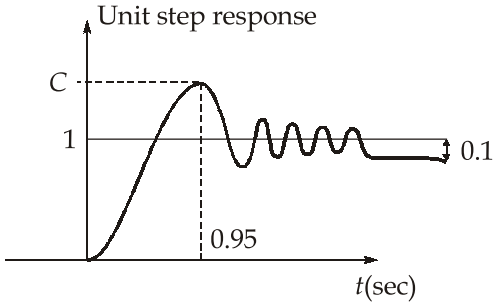


figure (b)

Determine:

(i) Values of A, B and C.

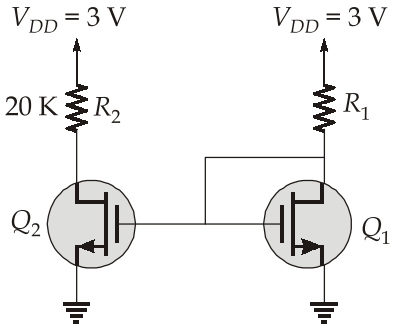
(ii) Bandwidth of the equivalent second order system.

[20 marks]

Q.2 (b) Consider the circuit in figure below. Let Q_1 and Q_2 have $V_t = 0.6$ V, $\mu_n C_{ox} = 200\ \mu A/V^2$, $L_1 = L_2 = 0.8\ \mu m$. $W_1 = 8\ \mu m$ and $\lambda = 0$.

(i) Find the value of R_1 required to establish a current of 0.2 mA in Q_1.

(ii) Find W_2 and a new value for R_2 so that Q_2 operates in the saturation region with a current of 0.5 mA and a drain voltage of 1 V.



[10 + 10 marks]

Q.2 (c) **(i)** Discuss the merits and demerits of representing a state model into

1. physical variable form,

2. phase variable form and

3. canonical variable form.

(ii) Derive the expression for the transfer function from the state model:

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

[15 + 5 marks]

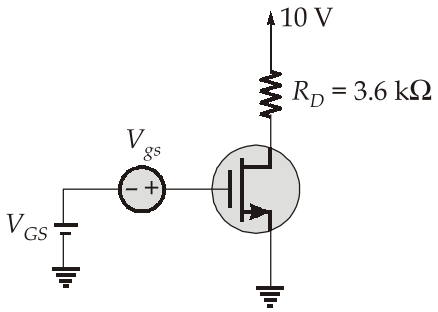
Q.3 (a) Consider the FET amplifier shown in below figure. It is given that V_t = 2 V, $K_n'(W/L)$ = 1 mA/V^2, V_{GS} = 4 V, V_{DD} = 10 V and R_D = 3.6 kΩ.

(i) Find the DC quantities I_D and V_D.

(ii) Calculate the value of g_m at the bias point.

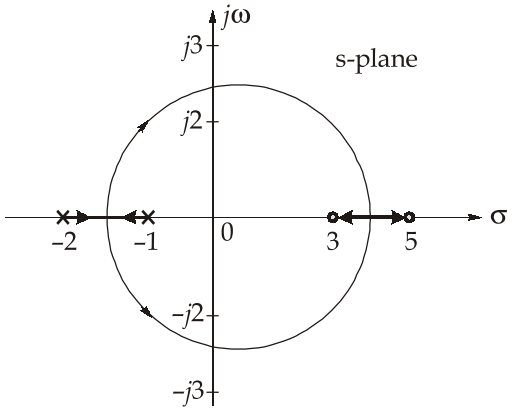
(iii) Calculate the value of the voltage gain.

(iv) If the MOSFET has λ = 0.01 V^{-1}, find r_0 at the bias point and calculate the voltage gain.



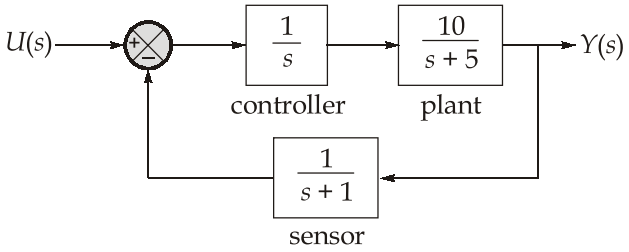
[20 marks]

Q.3 (b) **(i)** The root locus plot for the certain control system is shown below:



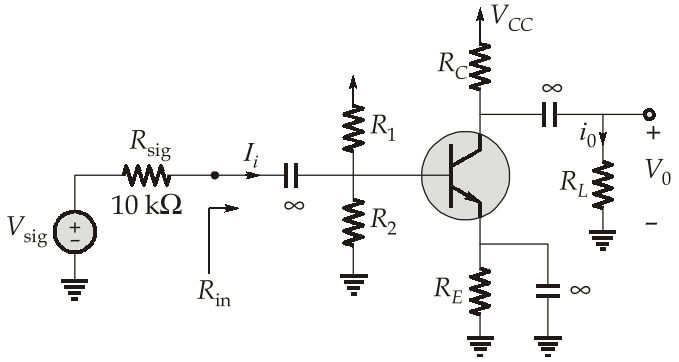
Find the break-away and break-in points for the above root locus plot.

(ii) Obtain a state-space model of the system shown in figure below:



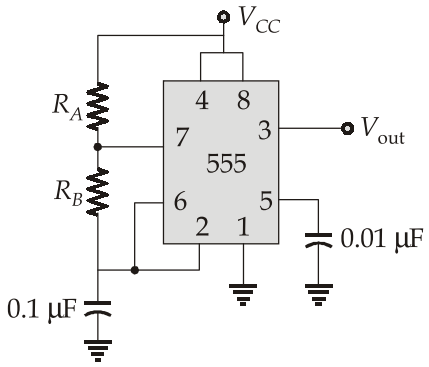
[10 + 10 marks]

Q.3 (c) Using the topology of figure below, design an amplifier to operate between a 10 kΩ source and a 2 kΩ load with a gain V_0/V_{sin} of –8 V/V. The power supply available is 9 V. Use an emitter current of approximately 2 mA and a current of about one tenth of that in the voltage divider that feeds the base, with the dc voltage at the base about one-third of the supply. The transistor available has β = 100 and V_A = 100 V. Use standard 5% resistor.



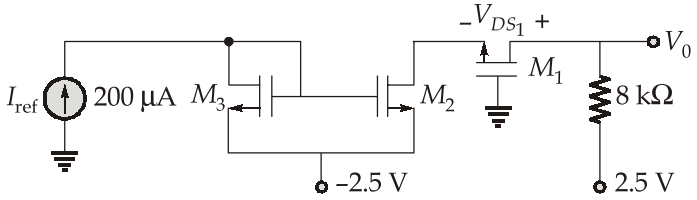
[20 marks]

Q.4 (a) **(i)** Consider the circuit diagram of a multivibrator as shown in the figure below:



The circuit is required to generate an output pulse train with a frequency of 2 kHz and a duty cycle of 75%. Calculate the required values for the resistances R_A and R_B to meet the specified frequency and duty cycle.

(ii) Consider the field effect transistor connected in the circuit given below:



The circuit employs a current mirror configuration to bias the output stages. All MOSFETs have a threshold voltage $V_{TN} = 0.4$ V and the channel length modulation parameters $\lambda = 0$. The process parameters for the transistors are given as:

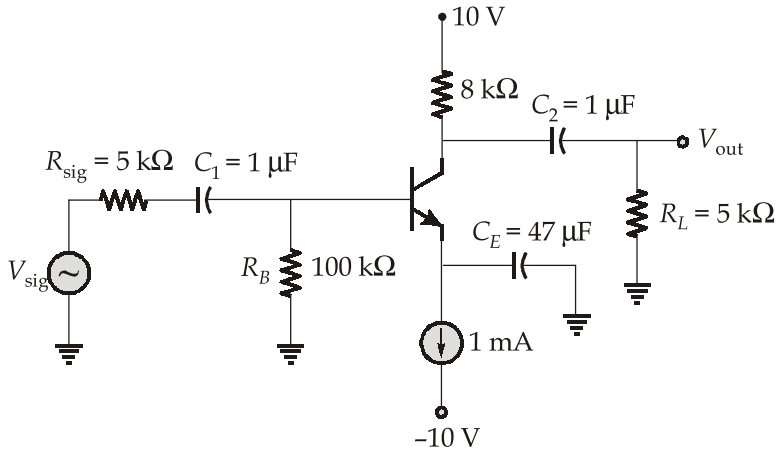
$$k_{n_1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 = 0.25\ \text{mA/V}^2$$

$$k_{n_2} = k_{n_3} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 = 0.15\ \text{mA/V}^2$$

Determine the drain-to-source voltage V_{DS1} of transistor M_1 and also calculate the gate-to-source voltages V_{GS3}, V_{GS2} and V_{GS1}.

[10 + 10 marks]

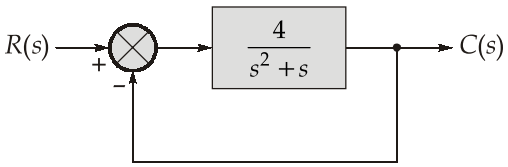
Q.4 (b) Consider the transistor circuit shown in the figure below:



Assume the transistor has β = 100, V_A = 100 V, C_μ = 1 pF and C_π = 7 pF. Calculate the upper 3 dB cutoff frequency considering only the input capacitance circuit. Also calculate the lower 3-dB cut-off frequency and the magnitude of mid-band voltage gain ($A_{V_{mid}}$) in dB. (Assume V_T = 25 mV)

[20 marks]

Q.4 (c) A closed-loop control system with unity feedback is shown in figure below. By using derivative control, the damping ratio is to be made 0.75. Determine the value of T_d. Also determine the rise time, peak time and peak overshoot without derivative control and with derivative control, if the input to the system is a unit-step.



[20 marks]

Section B : Control Systems + Analog Circuits + Adv. Electronics-2 + Electronic Measurements and Instrumentation-2

Q.5 (a) Draw state transition signal flow graph for the following system

$$\frac{d^2c(t)}{dt^2}+\frac{6dc(t)}{dt}+5c(t)=\frac{2dr(t)}{dt}+r(t)$$

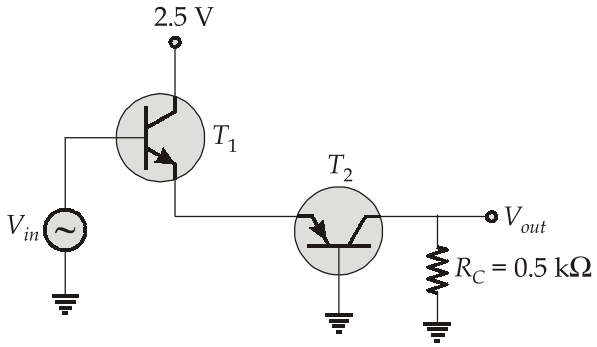
by means of

(i) Parallel decomposition.

(ii) Cascade decomposition.

[12 marks]

Q.5 (b) Consider the circuit shown in the figure below:



The value of emitter reverse saturation currents for transistors T_1 and T_2 are given as $I_{Es1} = 10I_{Es2} = 5 \times 10^{-16}$ A. The output has a maximum value of 0.2 V. Assuming that the two transistors have $\beta_1 = 99$ and $\beta_2 = 49$ at $V_T = 25$ mV. Determine the maximum value of the input voltage V_{in} that can be applied to the circuit.

[12 marks]

Q.5 (c) An LVDT has a maximum core motion of ±1.5 cm with a linearity of (± 0.3)% over that range. The transfer function is 23.8 mV/mm. If used to track work-piece motion from –1.2 to +1.4 cm, what is the expected output voltage? What is the uncertainty in position determination due to nonlinearity?

[12 marks]

Q.5 (d) Develop Mealy and Moore type of state diagrams for a sequence detector, to detect the sequence "110".

[12 marks]

Q.5 (e) **(i)** A potentiometer resistance transducer has a total resistance of 5 kΩ and a maximum displacement of 2 cm. If the maximum power dissipation is not to exceed 50 mW, determine the output voltage when input displacement is 0.75 cm.

(ii) A frequency counter with an accuracy of $\pm(1\ \text{LSD} + f_i \times 10^{-6})$ is employed to measure input frequencies of 100 Hz, 1 MHz and 100 MHz. Calculate the percentage measurement error in each case.

[6 + 6 marks]

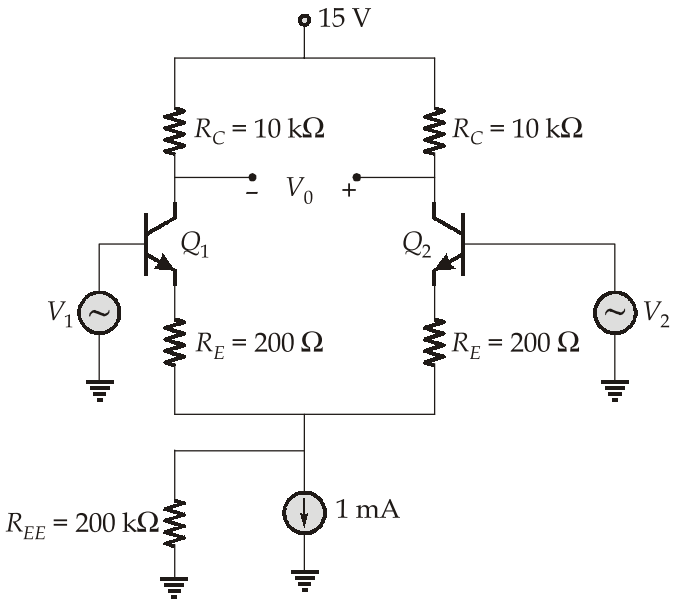
Q.6 (a) For the BJT differential amplifier shown in the figure below, assume $\beta = 100$, $V_T = 25$ mV and $V_{BE} = 0.7$ V. The circuit is biased with a 1 mA constant current source and $R_E = 200\ \Omega$ is connected to each emitter. Assume balanced output (V_0). Find:

(i) Differential Input Resistance.

(ii) Differential Voltage Gain.

(iii) Worse case common mode gain if R_C values are accurate to within ±1%.

(iv) CMRR in dB.



[20 marks]

Q.6 (b) Perform a complete physical design synthesis for a CMOS logic gate implementing the Boolean function:

$$Y = \overline{A(B+C)+DE}$$

(i) Draw the transistor-level circuit using Pull-Up Network (PUN) and the Pull-Down Network (PDN).

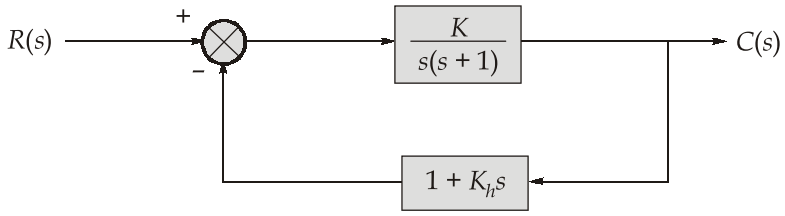
(ii) Identify a common Euler path to achieve an optimal gate ordering for the NMOS and PMOS networks.

(iii) Draw the stick diagram based on the identified Euler path.

(iv) Draw the final CMOS layout showing diffusion and metal layers.

[20 marks]

Q.6 (c) For the system shown below,



Draw the root-locus with $K_h = 0$ and K as variable. Obtain the value of K so that the system damping ratio is 0.158.

For the obtained value of K, draw the root-locus with K_h as variable. Find the value of K_h that improves the system damping ratio to 0.5.

[20 marks]

Q.7 (a) **(i)** A tachometer has the tachometer constant $K = 6$ V/Krpm (Krpm = 1000 revolutions per minute) and is connected to a 8-bit ADC which has input voltage range from 0 to 10 V.

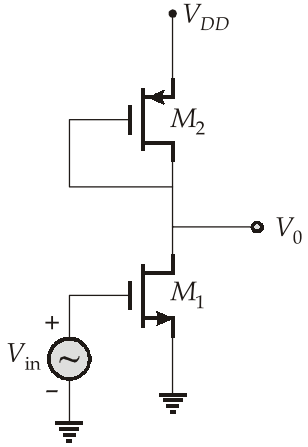
1. Calculate the maximum acceptable velocity which can be measured by the tachometer in this configuration.

2. Calculate the velocity measurement resolution of the tachometer with ADC.

(ii) Find the natural frequency of vibrations of a quartz plate of thickness 1.8 mm. Given: Young's modulus for quartz 8×10^{10} N/m^2 and and density 2650 kg/m^3. Calculate the change in the thickness required if the same plate is used to produce ultrasonic waves of frequency 2 MHz.

[10 + 10 marks]

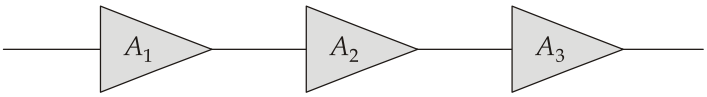
Q.7 (b) **(i)** Consider the MOS transistor circuit shown in the figure below:



Assume both the transistors are operating in saturation region with transconductance g_{m1} and g_{m2} respectively. The circuit is designed to produce an inverting unity gain buffer amplifier. Assume the ratio of processing parameters of the two transistors $\frac{k'_n}{k'_p} = \frac{26}{7}$ [where $k'_n = \mu_n C_{ox}$, $k'_p = \mu_p C_{ox}$ and $\lambda = 0$]. Find the ratio of the aspect ratios of the two transistors, $\frac{(W/L)_2}{(W/L)_1}$.

(ii) Three identical voltage amplifiers are connected in a cascade configuration. Each individual amplifer stage is characterized by the following parameters:

- Open-circuit voltage gain (A_{V_0}) : 50
- Input Resistance (R_i) : 2 kΩ
- Output Resistance (R_0) : 500 Ω



Calculate the overall voltage gain in decibels (dB).

[10 + 10 marks]

Q.7 (c) Explain in detail the working principle of Linear Variable Differential Transducer (LVDT). Write down its advantages and disadvantages.

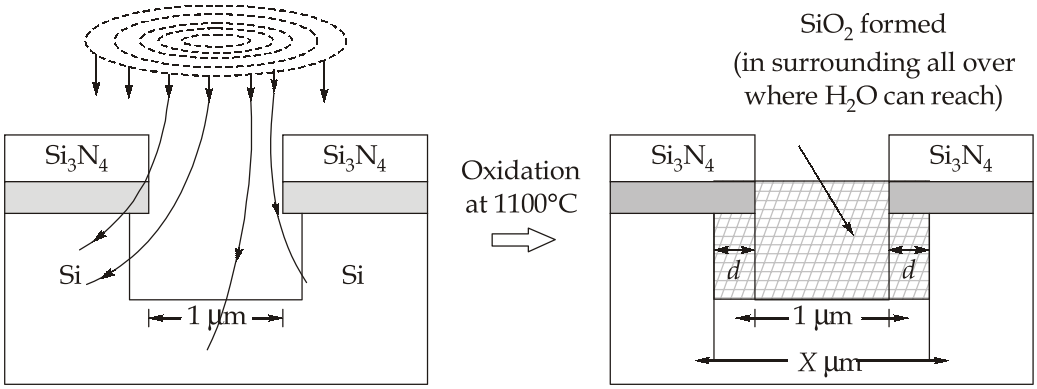
[20 marks]

Q.8 (a) **(i)** A vertical groove of width 1 μm is etched into a silicon (Si) substrate. The top surface is protected by a Silicon Nitride (Si_3N_4) mask as shown in the figure. The structure then undergoes steam oxidation at 1100°C to fill the groove with SiO_2.

Given:

- The ratio of silicon consumed (t_{si}) to the thickness of oxide formed (t_{ox}) is 0.46.
- The final oxide structure expands both into the substrate and above the original surface.

Determine the depth (d) to which the silicon is consumed and calculate the total thickness (X) of the SiO_2 layer formed.



(ii) A silicon wafer with an initial oxide thickness of x_i μm undergoes thermal oxidation for 1 hour and thickness of SiO_2 layer is found to be x μm. After 3 hours of further oxidation, the total oxide thickness is found to be $2x$ μm.

Given the Deal-Grove parameters:

- Parabolic rate constant, $B = 0.3\ \mu m^2/hr$
- Linear rate constant parameter, $A = 0.25\ \mu m$

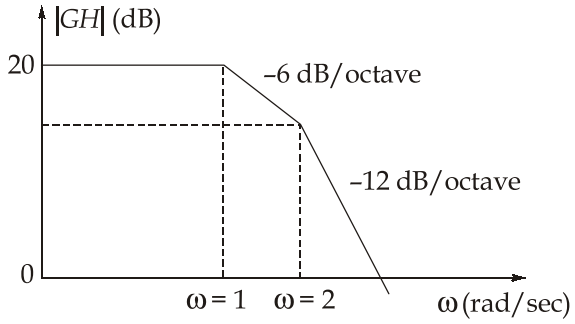
Calculate the values of the final thickness x and the initial thickness x_i.

[10 + 10 marks]

Q.8 (b) State the principle of operation and explain the working of digital frequency meter with the help of block diagram.

[20 marks]

Q.8 (c) The asymptotic approximation to the log-magnitude versus frequency plot (Bode plot) of a unity feedback control system is shown in the figure. The system is a minimum phase system.



Determine :

(i) Gain crossover frequency in rad/sec.

(ii) Phase crossover frequency.

(iii) Gain margin in dB.

(iv) Phase margin in degrees.

[20 marks]

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work