SECTION - A

There are FOUR questions in this section. Answer any THREE.

The questions are of equal value.

1. (a) What are the reasons for unsatisfactory operation of ordinary series motor when it is operated from ac source? Explain. Explain how in a universal motor, similar Torque-Speed characteristics are obtained when it is supplied either from dc or ac source.

(b) A universal series motor when operating on 220 V dc source draws current 10 A and runs at 1400 rpm. Find the new speed and power factor when connected to 220 V, 25 Hz supply (the motor current remains the same). The motor has total resistance of 1 ohm and total inductance of 0.1 H. Also find the torque developed by the motor when it is supplied from ac source.

2. (a) Explain with necessary Torque-Speed characteristics the operation of a repulsion-start induction-run and a repulsion-induction motor. Draw the circuit diagram of an electrically reversible repulsion motor and explain how it reverses the direction of rotation of the motor.

(b) Explain with necessary diagrams the operation of a linear induction motor. Mention its areas of application. Explain what magnetic levitation is.

An overhead crane in a factory is driven horizontally by means of two similar linear induction motors having rotors in the form of two steel I-beams on which the crane rolls. The 3-phase 2-pole linear stators, which are mounted on opposite sides of the crane, have a pole pitch of 50 mm and are energized by a variable frequency source. One of the motors has the following test results:

Stator frequency = 50 Hz, Power to stator = 5.5 kW, stator copper and iron loss = 1 kW, Crane speed = 4.8 m/sec. Find (i) synchronous speed and slip (ii) power input to the rotor (iii) copper loss in the rotor (iv) mechanical power developed and (v) propulsion force.

3. (a) Write the expression of torque in an electrostatic system in terms of applied voltage and rate of change of its capacitance with angular displacement. Derive the expression of average torque of an electrostatic motor supplied from ac source. What is the physical meaning of load angle δ of this motor?

(b) An electrostatic motor has N stationary plates and N rotating plates each consisting of two quarter-circular sections. The permittivity of the medium is ε₀. The supply voltage to the motor v varies with angular frequency of ω rad/sec and its peak value produces a maximum field intensity E between adjacent plates. Find the expression of maximum power output from the motor in terms of E and the volume V of the motor. How the maximum power per unit volume of the electrostatic motor can be increased?

Contd ........... P/2
4. (a) Explain how a hysteresis motor develops its torque. What are the advantages and disadvantages of this motor if compared to a reluctance motor? (b) Explain how thermal energy is directly converted to electrical energy in an MHD generator. What is conduction pump? Where is it used?

SECTION - B

There are FOUR questions in this section. Answer any THREE.
The figures in the margin indicate full marks.

5. (a) Describe the operation of a three phase 6/2 pole permanent magnet stepper motor with bipolar drive circuit. Consider the full step operating mode only. Show the possible drive circuit and gate signals of the MOSFET switches of this circuit. (25) (b) Briefly describe the principle of operation of a three phase reluctance motor. (10)

6. (a) Write the names of some common renewable energy sources. (4) (b) Write short notes on: (3 ½ ×2=7) (i) Wind energy (ii) Geothermal energy (c) Classify wind turbines according to their axis of rotation and define each type. (5) (d) What is the function of thyristors in controlled rectifiers? Briefly describe the operation of a three phase full wave controlled rectifier with the help of the waveforms of gate pulses and output voltage for firing angle equal to 60°. (19)

7. (a) What is a fuel cell? With a neat sketch of the membrane electrode assembly (MEA), describe the operation of a proton exchange membrane fuel cell (PEMFC). (17) (b) Describe the principle of operation of Schrage motors. How can supersynchronous speed be achieved in Schrage motors? (18)

8. (a) What is AMm in the context of solar energy? Describe the principle of operation of a p-n junction solar cell addressing the followings: (5+15=20) (i) Why the n-side is narrower than the p-side? (ii) Why is it important to have the minority carrier diffusion length as long as possible? (iii) Given, the crystalline silicon bandgap energy of 1.1 eV, what is the threshold wavelength for this material? (b) What is the effect of change of irradiance and temperature on the output current vs. voltage characteristics of a solar cell. (5) (c) What is BLDC? Describe its principle of operation briefly. State some of its possible applications. (10)
SECTION – A

There are FOUR questions in this section. Answer any THREE.

1. (a) Explain, with appropriate diagrams, the Deal-Grove model of oxidation. Also mention its limitations. (15)
   (b) Why oxidation rate is quicker in wet environment? Name the various applications of SiO₂. (10)
   (c) Compare the different sources for oxidation. Why does a CVD oxidation needs lower temperatures? (10)

2. (a) Explain, with proper diagram, the model for VPE. (20)
   (b) Compare the different processes of epitaxy, deposition, sputtering and evaporation. (15)

3. (a) Compare the advantages and disadvantages of vertical chamber and horizontal chamber systems for oxidation and/or diffusion. Use appropriate diagrams. (15)
   (b) Describe the recipe known as "RCA clean". (8)
   (c) How does post-implantation anneal improve crystal quality? Write the relative merits and demerits of CZ and float-zone methods. (12)

4. (a) In an evaporator system, the Al-charge is maintained at 1100 °C. If the evaporator planetary has a radius of 40 cm, and the dia of the crucible is 5 cm, what is the growth rate and arrival rate of Al atoms? [For Al: vapor pressure = 10⁻³ torr, mass density = 2700 kg/m³, M = 27.] (12)
   (b) Explain, with appropriate figures, the ten-step process of fabrication. (15)
   (c) Why does diffusion put a limit on high-density chips? (8)

Contd …….. P/2
There are FOUR questions in this section. Answer any THREE.

5. (a) Compare the issues and challenges of CMOS processes of the 1980's, 1990's and 2000's. (10)
(b) Explain, in detail, the process itself, advantages and disadvantages of a RIE system. (15)
(c) How does diffraction limit the standard lithography process? How does X-ray diffraction solve this problem? (10)

6. (a) What is the difference between pattern and feature size? (6)
(b) How do you explain the 'kink behaviour' observed in the diffusion profiles of Zn in GaAs? (14)
(c) Describe the Hall measurement and four-probe technique to determine doping concentration. (15)

7. (a) Explain shadowing, channeling and side-wall striation effect in RIE and implantation process. (12)
(b) Describe the detailed steps of packaging. (15)
(c) Explain pseudomorphic, metamorphic and relaxed epi-layers. (8)

8. Write short notes on:
   (a) Nanowires
   (b) MOCVD
   (c) PMMA
   (d) DRIE

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SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Show the system model for real time process scheduling. Compare EDF and rate
monotonic algorithms for process scheduling with necessary examples.  
(b) Define the following continuous media streams with necessary examples: 
   (i) strongly periodic (ii) aperiodic (iii) weakly regular (iv) discrete
(c) How is image represented? What are the steps of image recognition?

2. (a) What do you mean by flicker? How can you remove this problem?
(b) What is the significance of luminance and chrominances? Why are luminance and 
   chrominance preferred over RGB for transmitting video?
(c) Describe different approaches of transmitting animation with relative advantages and 
   disadvantages.
(d) Show with necessary example how the following controlling mechanism is done. 
   (i) Procedural control
   (ii) Tracking live action
   (iii) Kinematic and dynamics.

3. (a) Write down the relative advantages and disadvantages of Huffman and arithmetic 
    coding in JPEG image compression.
(b) Consider three components of an image with the following horizontal and vertical 
    resolutions:
    
    | Component 1 | Component 2 | Component 3 |
    |-------------|-------------|-------------|
    | H₁ = 500   | H₂ = 250    | H₃ = 1000   |
    | V₁ = 200   | V₂ = 300    | V₃ = 200    |

    Show the first four MCUs (Minimum Coded Units) during image preparation. What are 
    the pixels of 2nd block?
(c) Why is JPEG lossy? What are the source of losses? Explain.
(d) Write short note on quantization table in JPEG image compression.
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4. (a) How is motion vector calculated in H.261 video encoding? (8)
   (b) Describe roles of different types of frames in MPEG video compression technique
       with necessary explanations. (12)
   (c) Describe different components of Digital Television System. A Bangladeshi channel
       is made available to the viewers of a city of Colorado State of the USA. Show different
       ways of video transmission from the television station to the viewers mentioning
       different communication technology in a figure showing the communication mechanism. (15)

SECTION – B

There are FOUR questions in this Section. Answer any THREE.

5. (a) What are the characteristics of real time systems? How does it differ from
       multimedia systems? (10)
   (b) What do you mean by jitter? Describe the role of jitter and delay in video on demand
       and video conferencing applications with explanations. (10)
   (c) What are the main objectives of disk scheduling algorithms for multimedia file
       systems? Compare SCAN-EDF and mixed strategy as multimedia file systems. (15)

6. (a) Describe different levels of QoS in Multimedia Communication System with proper
       examples. (8)
   (b) Write down the concept of resources in multimedia communication. Present the
       resource management architecture in a multimedia communication system. (10)
   (c) Show the steps of multimedia call establishment. (10)
   (d) Describe the differences between peer to peer and layer to layer negotiation with
       examples. (7)

7. (a) Consider two PCs in the internet-connected to telephone lines through DSL modems
       of speed 1.5 Mbps and 512 Kbps. Show different types of QoS negotiation if a PC tries
       to establish a video conferencing call with the other using MPEG-1 video standards.
       You can assume that both PCs are capable to play and encode video streams of any
       standards. (15)
   (b) Why is scaling necessary in multimedia communication? Explain the following
       scaling used for Audio and Video communication:

           (i) Temporal (ii) Spatial (iii) Amplitude (iv) Colour

   (c) How is multicast application addressed? Describe the M-bone architecture for
       multicasting application. (10)

Contd ........... P/3
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8. (a) Why is TCP not used for multimedia communication? (5)
   (b) Explain the layers of multimedia transmission application over the Internet with justification. (7)
   (c) What are the features of XTP? Justify XTP for multimedia applications. (8)
   (d) In the figure, H₁, H₃ and H₄ are the sender of a multicast application. H₄ and H₅ want to listen from all the senders. Show the reservation table in the routers (R₁, R₂, R₃, R₄) if filtered reservation is specified using RSVP. (15)

![Diagram](image-url)

*Figure for question 8(d)*

In the figure H₁, H₃ and H₄ are the sender of a multicast application. H₄ and H₅ want to listen from all the senders. Show the reservation table in the routers (R₁, R₂, R₃, R₄) if filtered reservation is specified using RSVP.
1. (a) Explain the relative advantages and disadvantages of parametric and non-parametric techniques for estimating the power spectrum density (PSD) of a random process. Also, define the AR, MA and ARMA processes. Which one of these processes used in practice most and why? (20)

(b) Show that for an AR process
\[ y_{xx}(k) + \sum_{i=1}^{p} a_i y_{xx}(k-i) = 0 \text{ for } k > 0 \]
where \( x(n) \) represents the AR process. Also, show that
\[ \sigma_w^2 = y_{xx}(0) + \sum_{i=1}^{p} a_i y_{xx}(-i) \]
where \( \sigma_w^2 \) is the variance of the white noise process that is applied as input to the AR model, corresponding to the AR process \( x(n) \). (15)

2. (a) Determine the analytic expressions of the PSD of the following random processes: (15)
(i) \( x(n) = -0.81x(n-2) + W(n) - W(n-1) \)
(ii) \( x(n) = W(n) - W(n-2) \)
(iii) \( x(n) = 0.81x(n-2) + W(n) \)

Here, \( W(n) \) is a zero-mean white noise process with variance \( \sigma_w^2 \) and independent of \( x(n) \).

(b) The electrocardiogram (ECG) signals are often corrupted with power line interference and its harmonics. Describe an adaptive filtering scheme to reduce this interference, using the least-square criterion. Explain how the least-squares solution can be calculated by employing a recursive procedure. (20)

3. (a) Briefly describe the implementation of the short-time Fourier transform (STFT) using a filter bank. Also, show that unlike the traditional Fourier transform, the inverse STFT is not unique. (20)

(b) Describe the practical limitations of a least-mean square (LMS) algorithm and suggest ways to overcome them. (15)
4. (a) Write short notes on any three of the following:
   (i) Scaling function, (ii) admissibility condition of wavelet transform, (iii) LPTV property of a QMF bank, (iv) applications of multirate systems.
   (b) The PSD of a random process $x(n)$ is given by

   $$\Gamma_{xx}(W) = \sigma_W^2 \frac{|e^{j\omega} - 0.9|^2}{|e^{j\omega} - 0.8|^2 |e^{j\omega} + 0.9|^2}$$

   The process $x(n)$ is the output of a linear time-invariant system $H(z)$ where the input to the system is $W(n)$, a zero-mean white noise process with variance $\sigma_W^2$. Comment on the stability of the system.

SECTION - B

There are FOUR questions in this section. Answer any THREE.

5. (a) Develop a polyphase representation of an alias-free two-channel quadrature-mirror filter (QMF) bank. Determine the corresponding expression for the distortion transfer function. Draw the computationally efficient realization of the polyphase representation and explain how the efficiency is achieved.

(b) Consider the analysis-synthesis filter bank shown in Fig. for Q. 5(b). Develop the input-output relation of this structure in the $z$-domain. Let $H_0(z) = (1 + z^{-1})/2$ and $H_1(z) = (1 - z^{-1})/2$. Determine the synthesis filters $G_0(z)$ and $G_1(z)$ so that the structure of the figure is a perfect reconstruction filter bank.

6. (a)
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Contd… Q. No. 6(a)

Fig. for Q. 6(a) shows a four-channel QMF bank with filters of equal passband width for all channels. Develop the equivalent representation of the filter bank using filters of unequal passband widths with necessary equations and frequency responses.

(b)

Show that the multirate system given in Fig. for Q. 6(b) is time-invariant. Determine the transfer function of the system.

7. (a) Show that \( \mathbb{E}[P_{x x}(F)] \) converges to \( \Gamma_{x x}(F) \) as \( T_0 \to \infty \), where

\[
P_{x x}(F) = \int_{-T_0}^{T_0} R_{x x}(\tau) e^{-j2\pi F \tau} d\tau
\]

(b) Show that the periodogram is not a consistent estimate of the true power density spectrum.

8. (a) Describe the direct and indirect methods to obtain the energy density spectrum of a deterministic signal with finite duration from its discrete samples. Explain the problems of spectral leakage and broadening of the spectrum and their competing requirements.

(b) Define the quality of an estimator for power density spectrum. Next, find and compare the defined qualities between two power spectrum estimation methods, namely, Periodogram and Bartlett.
SECTION - A

There are FOUR questions in this Section. Answer any THREE.

1. (a) Explain the statement, "NMOS pass transistor passes good '0' but bad '1' " . For the connection of the NMOS pass transistors shown below find the output voltage $V_{out1}$ and $V_{out2}$. The following data are given: $V_{DD} = 5V$, $\gamma = 0.5$.

![Fig. for Q No 1(a)]

(b) What is sheet resistance? A 100 nm CMOS process uses a polysilicon layer as resistors. The resistivity of the polysilicon layer is $20 \times 10^{-6} \, \Omega \cdot m$ and the thickness is 500 nm. Calculate the number of squares needed to form a 5 k$\Omega$ resistor.

(c) Show the circuit diagram of a pseudo NMOS inverter. The inverter is designed such that output voltage becomes 0.2 V when the input voltage is High (5 V). Calculate the aspect ratio of the inverter i.e. the ratio of driver transistor size to load transistor size. The following data are given: $\mu_n C_{ox} = 120 \mu A/V^2$, $\mu_p C_{ox} = 60 \mu A/V^2$, $V_{ton} = 1V$, $V_{top} = -1V$, $V_{oa} = 5 V$, $\gamma = 0.5$. Assume the body of the NMOS transistor is connected with the ground and the body of the PMOS transistor is connected with $V_{DD}$.

2. (a) In a 180 nm CMOS process the minimum gate length and width are $2\lambda$ and $4\lambda$, respectively. A minimum sized and minimum gate length CMOS inverter is designed such that the inversion voltage becomes $V_{DD}/2$. The following data are given: $\mu_n C_{ox} = 120 \mu A/V^2$, $\mu_p C_{ox} = 60 \mu A/V^2$, $V_{ton} = 1V$, $V_{top} = -1V$, $V_{oa} = 5 V$, $\gamma = 0.5$.

(i) Calculate the aspect ratio of the NMOS and the PMOS transistor.

(ii) In the transfer curve show the minimum and maximum input and output voltage levels and hence give an expression of low level and high level noise margin.

(iii) Now suppose that the designer increased the aspect ratio of the NMOS transistor ten times than that obtained in (i). What changes in noise margin do you expect?
(b) A buffer chain circuit is to be designed for a clock signal which will drive 1000 logic gates. The input capacitance of each of the logic gate is 12 fF and the output capacitance is 4 fF. The minimum sized inverter in the process has an input capacitance of 3 fF and output capacitance is also 3 fF. Find the size (n) and the number of stages (m) of the required buffer chain. You have to derive any equations used in your calculations.

3. (a) Derive the expressions for rise time and dynamic power dissipation of a CMOS inverter.

(b) The output of a CMOS inverter is connected to the input of a logic gate as shown in Fig. for Q. No. 3(b). Calculate the rise time, fall time and dynamic power dissipation of the CMOS inverter. The following data are given: Process Technology 500 nm CMOS process. \( \mu_{n}C_{ox} = 120 \mu A/V^2 \), \( \mu_{p}C_{ox} = 50 \mu A/V^2 \), Gate oxide capacitance \( C_{ox} = 35 fF/\mu m^2 \). Source/Drain bottom Junction capacitance of both NMOS and PMOS, \( C_{jsb} = 10 fF/\mu m^2 \), \( M_{j} = 0.33 \), Source/drain side wall capacitance of both NMOS and PMOS, \( C_{jsw} = 0.2 fF/\mu m \). \( M_{jsw} = 0.1 \), \( \psi_{0} = 0.7 \) V at room temperature, poly-substrate capacitance = 15 fF/\mu m^2, Metal-substrate capacitance = 6 fF/\mu m^2. All poly width = 2\( \lambda \), all metal width = 2\( \lambda \) except \( V_{DD} \) and GND bus, poly extending N-Diffusion/P-Diffusion = 1\( \lambda \). frequency, \( f = 500 \) MHz.
4. (a) Explain briefly the necessity of the following design rules: (i) Poly overlap Diffusion = 2λ, (ii) Floating NWELL not allowed, (iii) Metal overlap contact = 1λ, (iv) Spacing of NWELL to P-Diffusion = 6λ.

(b) Explain briefly the meaning of the following SPICE MOS model parameters: (i) KP, (ii) GAMMA, (iii) MJ, (iv) LAMBDA, (v) PB.

(c) Draw the truth table of a 3-input majority circuit in which the output is '1' when majority of the input is '1'. Minimize the Boolean expression of the output and implement the circuit in (i) CMOS, (ii) Pseudo NMOS, (iii) footed dynamic CMOS.

(d) A 4-input NOR gate is designed for worst case equal rise and fall times. If μn = 2.5μp, calculate the aspect ratio of the PMOS transistor in terms of aspect ratio of the NMOS transistor.

SECTION B
There are FOUR questions in this Section. Answer any THREE.

5. (a) Explain the following: (i) positive mask, (ii) negative mask, (iii) positive photoresist and (iv) negative photoresist.

Show the process sequence of fabricating an inverter in a dual well CMOS process. In each sequence show the mask diagram and the device cross sectional diagram up to that sequence.

(b) Design an n-bit parity generation circuit in bit sliced and structured way. The required response is such that Z = 1 if there is even number of 1s in the input and Z = 0 if there is odd number of 1s. Show the schematic diagram of the parity generator including the connection of the first cell. Draw the layout diagram of the leaf cell using CMOS technology in a modular way such that interconnections between cells are achieved when cells are butted together.

6. (a) You have to design a 64-bit adder. The delay through one adder cell is 1 nsec and the delay through the multiplexer cell is 2 nsec. Calculate the delay if the adder is designed as (i) ripple carry adder, (ii) carry select adder and (iii) carry skip adder. Make any reasonable assumptions.

(b) Design a 16 bit carry look ahead (CLA) adder in 4x4 block CLA adder. Show the schematic diagram of the complete system and the detailed circuit level implementation of the block. Explain the operation of the system.

(c) In a 100 nm CMOS process the minimum width of metal is 3λ. The metal layer consists of copper conductors of thickness 1 μm. The electro-migration limited maximum current density of copper wire is 5 mA/μm². Calculate how many nMOS 9:1 inverters can be driven by a minimum sized metal interconnect. Assume the resistance of the driver transistor is 10 kΩ and VDD = 5V.

Contd ........... P/4
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7. (a) Show the NOR-NOR implementation of a PLA circuit which will provide the following outputs:

\[ Z_1 = \overline{a} \overline{b} c + \overline{a} \overline{c} d + \overline{a} \overline{b} \overline{d} \]
\[ Z_2 = a \overline{b} c d + a b d \]
\[ Z_3 = b c + a b \overline{d} + \overline{a} c d \]

(b) Show the circuit level implementation of a 2 × 2 SRAM cell using 6-T SRAM core cell. Clearly show in your design the pre-charge circuit, column select and row select circuits and the sense amplifier circuit. Explain how the read and write operations are performed showing the first row and second column cell as an example. Explain how the sense amplifier accelerates the READ operations.

8. (a) Name the four fault models most commonly used for CMOS circuits and explain them.

(b) Three faults S₁, S₂ and O₁ occurs in the circuit shown (Fig. for Q8(b)). Assuming fault occurs one at a time, show the test vectors that will identify the faults.

(c) Show the circuit diagram and device cross-sectional diagram of a one transistor DRAM cell. Explain the operation of the circuit.
SECTION - A

There are FOUR questions in this section. Answer any THREE.

1. (a) Deduce the far field components and expressions for power and radiation resistance of Hertzian dipole in free space.
   (b) A Hertzian dipole of length 5 cm is situated in free space. If the maximum current is 10 A and its frequency is 800 MHz, determine (i) its electric and magnetic fields in the far zone, (ii) the average power density and (iii) radiation resistance.

2. (a) Deduce the properties of a small circular loop antenna.
   (b) The current in a small circular loop antenna of radius 10 cm is \(100 \cos(\omega t - 30^\circ)\) A, where \(\omega = 300\) Mrad/s. If the medium is free space, write the expressions for the far fields in the time domain. Compute the power radiated by the antenna and its radiation resistance.

3. (a) What are the purposes of arraying antenna elements? Derive the properties of an endfire array.
   (b) Derive the properties of a broadside array.

4. (a) With neat sketches describe the working principle of a reflex klystron.
   (b) With neat sketches describe the working principle of a traveling wave tube (TWT) amplifier.

SECTION - B

There are FOUR questions in this section. Answer any THREE.

5. (a) Starting with the voltage and current wave equations, deduce the analytical expression of the complex reflection coefficient \(\rho\) for an ideal transmission line of characteristic impedance \(Z_0\) and of length \(l\), terminated with a mismatched load impedance \(Z_L\) ohms.

Contd .............. P/2
(b) Compute the input impedance at a distance of 1.41 cm from the load in a lossless transmission line of 75 ohm characteristic impedance in which the reflection coefficient at the plane is 0.1∠45°. The line is filled with a material of dielectric constant of 1.4 and fed with a 3 GHz signal. (Smith chart shall not be used).

(c) Starting with the analytical expression of the input impedance, deduce the expression of input impedance of a 4.75λ long transmission line of characteristic impedance $Z_0$ terminated with a load impedance of $Z_L$.

(d) Deduce the expression of input impedance of an open circuit transmission line of characteristic impedance $Z_0$ and of length $l_1$.

6. (a) A microwave transmission line of characteristic impedance of 50 ohms filled with a material of dielectric constant of 2.0 and is fed with a signal of 4 GHz. The input impedance at one plane along the length of the line is $35 - j35$ ohms.

(i) Find the distance in cm of the plane toward the generator from the above mentioned plane at which the input impedance is $25 + j20$ ohms.

(ii) Find the distance in cm of the plane toward the load from the first plane where the input impedance is $35 + j35$ ohms.

(iii) Marking the point on the Smith chart read the value of the VSWR.

(iv) Find the distance in cm from the load plane toward the generator on the same line, where the input impedance is $0 + j41.666$ ohm if the load is replaced by a short circuit (Use Smith Chart).

(b) A signal of 6 GHz is propagating through a parallel plane waveguide consisting of two copper conductor planes having a spacing of 3 cm and filled up with a dielectric material of dielectric constant 1.5. Considering TE_{10} propagating through the waveguide, compute the values of (i) cutoff frequency, (ii) phase velocity, (iii) group velocity, (iv) guide wavelength, (v) wave impedance and (vi) the electric field components.

7. (a) With necessary analytical expressions and supporting diagrams, write the steps (of the procedure) which need to be followed to solve a quarter wave transformer impedance matching problem for a mismatched complex load.

(b) With necessary analytical expressions and supporting diagrams write the steps (of the procedure) which need to be followed to solve a single stub impedance matching problem.
(e) A microwave generator operating at 5 GHz feeds into a 18 cm long transmission line of characteristic impedance 75 ohms. A load of 52.5-j60 ohms is connected at the end of the transmission line. A single-stub tuner is to be connected with this system located at a distance $d$ from the load plane toward the generator to obtain matching. Find the distance $d$ in cm and the length of the stub $l$ in cm for perfect match. The dielectric material used inside the microwave transmission line has a dielectric constant of 1.4. Give all possible values of $d$ and $l$ in cm. (Use Smith Chart)

8. (a) Taking the vertical direction as y-axis and the direction of propagation as the z-axis write the analytical expressions of (i) the Electric field components, (ii) guide wavelength, (iii) wave impedance, (iv) cutoff frequency for TE and TM waves propagating through a rectangular waveguide.

(b) Compute the values of (i) cutoff frequency, (ii) wave impedance, (iii) guide wavelength and (iv) write the expressions of field components (with appropriate values) for a TE_{10} wave propagating through a rectangular waveguide having the dimensions $a = 2.3$ cm, $b = 2$ cm and filled up with a material of dielectric constant of 1.4.

(c) A rectangular cavity resonator made of copper plates, is filled with a dielectric material of dielectric constant $= 2.0$. The length 'd' of the cavity is 3 cm and the height of the cavity 'b' is 1.5 cm. (i) For the cavity resonator to be resonant with a TE_{10} wave inside it what should be the dimension of the width 'a' in cm (ii) Compute the resonant frequency of the cavity resonator.

---------------------------------------------
The Complete Smith Chart
Black Magic Design
L-4/T-1/EEE

Date: 23/07/2013

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

Sub: EEE 473 (Power Electronics)

Full Marks: 210 Time: 3 Hours

The questions are of equal value.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are FOUR questions in this Section. Answer any THREE.

1. (a) Classify DC-DC chopper circuits according to their quadrant of operations.
   (b) Draw the circuit diagram of a Jone's chopper (dc-dc converter) circuit, SCR gate voltages, input and output voltages of the circuit for a R-L-EMF load. Describe the operation of the circuit in details.
   (c) Describe the operation of the following SCR chopper circuit where T1 is the main SCR and T11 is the Commutating SCR.

2. (a) In the following single phase controlled rectifier circuit with the wave forms shown in the diagram, what is the input power factor?

(b) Following is the circuit of a half-wave/half-bridge three phase uncontrolled rectifier. Starting with three phase line to neutral voltages, draw the input currents (all three phases) of the rectifier.

\[ V_{an} = V_{mn} \sin (\theta - 120) \]
\[ V_{bn} = V_{mn} \sin (\theta - 240) \]
\[ V_{cn} = V_{mn} \sin (\theta - 120) \]

Contd …….. P/2
3. (a) Draw the circuit diagram of a three phase SCR voltage controller with Y-connected resistive loads. With appropriate input \( V_{LN} \), \( V_{LL} \), output \( V_{LN} \), \( V_{LL} \), phase and line currents and gate pulses of six SCRs of the circuit, explain the operation of the circuit for firing angle \( \alpha = 60^\circ \).

(b) Explain the operation of the following single phase voltage controller circuits and describe the difference between them.

4. (a) Draw the circuit of a three phase voltage source square wave MOSFET inverter. With appropriate gate/base signals for six switches, input/output dc, line to line and line to neutral voltages of the load (R Y Connected) explain the operation of the inverter.

(b) What is a current source inverter? Explain the operation of the (Fig. Q. 4(b) following single phase SCR current source inverter. Explain how the main SCRs commutates in the circuit without any additional SCR commutation circuit.

(b) Derive the Fourier series of the line to neutral voltage of a three phase square wave voltage source inverter. Load is Y connected R-L load. Also find the Fourier series of the current through R-L load.
5. (a) What is secondary breakdown? Explain why secondary breakdown occur in BJT and Thyristors but not in MOSFETs.
(b) What is a snubber circuit? Explain the usage of snubber circuits in SCR.
(c) Define latching current and holding current of an SCR.
(d) Explain why BJT's cannot be operated in parallel to increase current ratings.

6. (a) What is a dual converter? Why inductors are inverted between the forward and reverse converters of a dual converter?
(b) A three phase dual converter supplies power to a dc motor. The supply voltage is 3%, 415V (line to line). If the motor needs an armature voltage of -295 Vdc, determine the firing angles $\alpha_1$ and $\alpha_2$ for the forward and reverse converters.
(c) Draw and explain the topology of a single phase cyclo converter.

7. (a) What are the basic differences between a chopper and a switching regulator?
(b) Draw the topology of a buck regulator and hence deduce the output voltage, current ripple and voltage ripple equations.
(c) Design a switching buck regulator with the following rated values:
   - Input voltage range = 7 V to 35 V dc
   - Output voltage = 5 V ± 10 mV dc
   - Ripple current less than 10 mA.
   - Switching frequency range 25 kHz to 35 kHz.
   - Output power = 20 watts.

8. (a) Derive an expression for the dc output voltage of a buck-boost regulator.
(b) What is a flyback converter? How core saturation problem is addressed in a flyback converter?
(c) A permanent magnet dc motor is used in robotic arm and is driven from a stepdown chopper. The supply is from a battery of 12V dc with internal resistance of 0.1 Ω.
The motor draws a power of 25 w at an armature current of 3.5 A. Neglecting the switching loss, determine the duty cycle of the chopper.
L-4/T-1/EEE

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA
Sub: EEE 435 (Optical Fiber Communication)

Full Marks: 210  Time: 3 Hours
USE SEPARATE SCRIPTS FOR EACH SECTION
The figures in the margin indicate full marks.

SECTION – A

There are FOUR questions in this section. Answer any THREE.

1. (a) What is an optical fiber? State the merits of optical fiber over conventional waveguides. Show the ray propagation through different types of fibers. Comment on their relative merits and limitations.  
(b) Show that the numerical aperture (NA) of a fiber is given by 
\[ NA = \sqrt{n_1^2 - n_2^2} \approx n_1 \sqrt{2 \Delta} \]  
(c) What are the causes of attenuation in a glass fiber? Discuss the phenomenon behind the attenuation in a fiber. Draw the loss characteristic curve of a silica fiber and show the operating windows for transmission.

2. (a) Distinguish between inter-modal and intra-modal dispersion in a fiber. Discuss the effect of dispersion on the bandwidth and allowable bit rate through a fiber.  
(b) Derive the following relationship for an SMF: 
\[ \sigma_{rms} = L \sqrt{\frac{8}{C}} \left| \frac{d^2 n}{d\lambda^2} \right| \sigma_\lambda \]  
where the symbols have their usual meanings.  
(c) A silica fiber has the material dispersion defined as \[ \frac{d^2 n}{d\lambda^2} = 0.08 \ \text{pm}^{-2} \]. The refractive index of the core is 1.55 and relative refractive index difference is 2%. The source used has a FWHM linewidth of 0.15 nm. Determine:  
(i) rms pulsewidth due to intra-modal dispersion at the output of 1 Km fiber;  
(ii) rms pulsewidth due to intermodal dispersion at the output of 1 Km fiber;  
(iii) bandwidth of 1 Km fiber;  
(iv) maximum allowable bit rate through a fiber of length 10 Km.

3. (a) Discuss the principle of optical FDM and Wavelength division multiplexing (WDM) and comment on their applications.
4. A fiber-optic link is based on SMF of 10 segments each of length 22.5 Km which are connected through couplers of loss 1 dB each. The source is a laser of half-width-half-maximum linewidth of 0.075 nm. The rise time of the laser driver circuit is 2.5 ns. The receiver is based on a PIN photodetector of rise time 5 ns. The receiver load resistance is 50 ohm and the LPF bandwidth is 560 MHz. The photodetector has a sensitivity of -60 dBm. The material dispersion coefficient of the fiber is 16 ps/Km-nm. The optical fiber is coupled to the source and detector via optical couplers of loss 1.2 dB each. Determine:

(i) the minimum power required for the laser;
(ii) the maximum available bandwidth of the fiber link limited by system risetime;
(iii) bandwidth-distance product of the fiber link;
(iv) the signal-to-noise ratio at the output of the receiver LPF if the quantum efficiency of the photodetector is 85% at the operating wavelength of 1550 nm.

SECTION – B
There are FOUR questions in this section. Answer any THREE.

5. (a) Explain the operation of a semiconductor laser diode showing its basic structure and band diagram. Derive the necessary conditions of oscillation.
(b) Compare the input-output characteristics and spectral characteristics of LED with laser.
(c) State the advantages of ILDs over LEDs. Mention the applications of different types of LEDs.

6. (a) Sketch the basic structure of a PN photo-detector (PD) under reverse bias and explain its operation. Explain step by step how it is improved in PIN PD and APD.
(b) Write down the advantages and disadvantages of APD compared to PIN PD. How the problem of excess noise in APD is mitigated in silicon reach through APD (RAPD).

(c) An APD has a quantum efficiency of 50% at 0.8 μm. When illuminated with a radiation of this wavelength it produces an output current of 10 μA after avalanche gain with a multiplication factor of 250. Calculate received optical power to the device. How many photons per second does this correspond to? Determine the wavelength above which the device will cease to operate considering the bandgap energy of the material as 1.43 eV at 300 K.

7. (a) Describe the direct detection technique in IM/DD optical communication system and derive the expression of SNR and BER considering PIN receiver. What is receiver sensitivity?

(b) Show the block diagrams of different coherent detection techniques in optical communications. State the relative merits and demerits of using coherent detection.

(c) A PIN photodiode incorporated into an optical receiver has a quantum efficiency of 80% at operating wavelength of 1300 nm. The average incident optical power to photodiode is 100 μW and the post-detection bandwidth of the receiver is 5 MHz. It has an amplifier with noise figure of 3 dB. The dark current in the device is negligible and the load resistance is 100 Ω at operating temperature of 30°C. Calculate the SNR at the output of the receiver.

8. (a) Mention different types optical amplifiers. Show their common applications in optical fiber communication systems. Draw a schematic diagram of SOA and briefly describe its operation.

(b) What are the rare-earth-doped fiber amplifiers? Explain the operating principle of EDFA and compare its gain spectrum with that of SOA.

(c) Write short note on (any ONE):
   (i) Fiber FBT couplers
   (ii) EOPM

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SECTION A

There are FOUR questions in this section. Answer any THREE.

1. (a) Why electronic property of amorphous, polycrystalline and crystalline semiconductors are different? Discuss mobility and optical absorption characteristics of these materials. How these properties can be explained with the help of energy band structure?

(b) Show the compositional dependence of the direct and indirect conduction band minima in the \( \text{Al}_x\text{Ga}_{1-x}\text{As} \) mixed crystals and determine the effective band gap at direct to indirect transition. Given that,

\[
E_{\text{g}}^d(x) = \begin{cases} 
1.425 + 1.247x, & (x \leq 0.45) \\
1.425 + 1.247x + 1.147(x - 0.45)^2, & (x > 0.45) 
\end{cases}
\]

\[
E_{\text{g}}^i(x) = 1.9 + 0.125x + 0.143x^2
\]

\[
E_{\text{g}}^c(x) = 1.708 + 0.642x
\]

2. (a) Explain the term pseudomorphic. Why critical thickness is important during epitaxial growth? Discuss the effect of biaxial strain on bandstructure and impact of biaxial strain on the performance of electronic device.

(b) Discuss why \( \beta \) is decreased with \( I_C \) at low and high injection levels. How base transport factor limits common emitter current gain?

3. (a) Explain the influence on the device characteristics if Ge is incorporated in the base of silicon bipolar transistor. Discuss why polysilicon Emitter structure is used in Si BJT?

(b) How band gap narrowing affects BJT and HBT performances? Consider a uniform doped Si npn transistor in which \( x_e = x_b, \ N_{ae} = 5 \times 10^{19} / \text{cm}^3, \ N_{ab} = 2 \times 10^{16} / \text{cm}^3, \ D_n = 25 \text{cm}^2 / \text{s}, \ D_p = 10 \text{cm}^2 / \text{s}. \) Calculate \( \beta \) at 300 K and 350 K when the bandgap narrowing effect is taken into account for moderate injection level.

Contd ........... P/2
4. (a) Elaborate the physical factors in BJT those affect transistor cutoff frequency. How can higher speed be obtained in HBT?

(b) Explain TEBT. Estimate the factor increasing $\beta$ in an HBT with a wide bandgap emitter having emitter-base valence band discontinuity of 0.2 eV at 300 K.

SECTION – B

There are FOUR questions in this section. Answer any THREE.

5. (a) Prove that, for a JFET, the drain current is given by,

$$I_{D1} = I_{p1} \left[ 3 \frac{V_{GS}}{V_{p0}} - 2 \left( \frac{V_{DS} + V_{th} - V_{GS}}{V_{p0}} \right)^{\frac{1}{2}} + 2 \left( \frac{V_{DS} - V_{GS}}{V_{p0}} \right)^{\frac{1}{2}} \right]$$

Here, the symbols have their usual meanings.

(b) For an n-channel GaAs MESFET, $a = 0.5 \, \mu m$, $N_d = 6 \times 10^{15} \, cm^{-3}$, $N_c = 4.7 \times 10^{17} \, cm^{-3}$, $\Phi_{th} = 0.95 \, eV$ and $\varepsilon_S = 13.1 \varepsilon_0$. Determine the value of threshold voltage at 300 K temperature.

6. (a) Describe the operating principle of HEMT with neat sketch of quantum well structure.

(b) Consider an N-Al$_{0.3}$Ga$_{0.7}$As- intrinsic GaAs abrupt heterojunction structure which can be used as HEMT. Assume that the AlGaAs is doped with $N_d = 3 \times 10^{18} \, cm^{-3}$ and has a thickness of 350 Å. Let $\Phi_B = 0.89 \, eV$, $\Delta E_c = 0.24 \, eV$ and $\varepsilon_N = 12.2 \varepsilon_0$. Determine the value of threshold voltage at 300 K temperature.

7. (a) Write down the definition of heterojunction in brief. State when Anisotype, Isotype heterojunctions are formed. Draw sample band diagram (before contact) of straddling gap, staggered gap and broken gap heterojunction structure.

(b) Prove that, for an nP heterojunction, the expression of built in potential barrier is given by,

$$eV_n = -\Delta E_c + kT \ln \left( \frac{n_{o0}}{n_{p0}} \cdot \frac{N_{ee}}{N_{en}} \right)$$

Here, the symbols have their usual meanings.

Contd ............. P/3
(c) For heterojunctions in the GaAs-AlGaAs system, the direct bandgap difference $\Delta E_g$ accommodated approximately 2/5 in the conduction band and 3/5 in the valence band. For an Al composition of 0.30, the AlGaAs is a direct bandgap material with $E_g = 1.80$ eV.

Calculate (i) $\Delta E_c$, (ii) $\Delta E_v$, and (iii) (Electron effinity, $\kappa_{AlGaAs}$) if (electron effinity, $\kappa_{GaAs} = 4.07$ eV).

Given the direct band gap of GaAs is 1.42 eV.

8. (a) Briefly explain, only the forward bias effect of a metal-$n$-semiconductor Schottky Barrier Diode using a sample energy band diagram.

(b) The Schottky Barrier Height of a Silicon Schottky junction is $\Phi_{Bn} = 0.6$ eV, the effective Richardson constant is $A^* = 115$ A/K$^2$-cm$^2$.

Determine (i) The ideal reverse saturation current density at 300 K, (ii) The diode current density for $V_a = 0.35$ V.

(c) Consider an ideal Chromium-$n$-Si Schottky diode at a temperature of 300 K with $N_d = 3 \times 10^{15}$ cm$^{-3}$ and $N_c = 2.8 \times 10^{19}$ cm$^{-3}$. Determine (i) The ideal Schottky Barrier Height and (ii) Maximum electric field at zero bias. Given, the work function of Chromium is 4.5 eV, electron affinity of Silicon is 4.01 eV and $\varepsilon_S = 11.7 \varepsilon_0$. 

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SECTION – A

There are FOUR questions in this section. Answer any THREE. The figures in the margin indicate full marks.

1. (a) What are the major components of a coal fired power plant? Also indicate the land requirements for each component in percent of total requirement. (10)
   (b) Describe, in very brief, the different conditions to be considered to determine the location of a new thermal power station. (25)

2. (a) What is the condition that a hydro plant should satisfy so that it can be operated as a base loaded unit. What are the major components of a hydro plant? What is water hammer? (20)
   (b) A power system has the units of capacity shown in the following tabulation, with the indicated order of efficiency: (15)

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>Capacity, MW</th>
<th>Order of efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>3</td>
</tr>
</tbody>
</table>

   For the above conditions, show the capacity schedule in a tabulation form.

3. (a) Describe the general objectives of electric energy rate. (10)
   (b) With simple curves, describe the difference between Block-Meter Rate and Hopkinson Demand Rate. (13)
   (c) A Wright demand rate is quoted as follows: (12)

   For energy purchased monthly, the equivalent of
   1. The first 50 hr. use of max\textsuperscript{m} demand at 9.00 taka per kWhr.
   2. The next 50 hr. use of max\textsuperscript{m} demand at 6.00 taka per kWhr.
   3. The next 100 hr. use of max\textsuperscript{m} demand at 4.50 taka per kWhr.

   Contd ........ P/2
4. The next 200 hr. use of max. demand at 3.00 taka per kWhr.
5. All energy in excess of foregoing blocks at 1.50 taka per kWhr.
   (i) Compute the bill for a monthly energy consumption of 432000 kWhr with a maximum demand of 1600 kW. Compute the unit energy cost corresponding.
   (ii) Find the lowest possible bill for this energy consumption and the corresponding unit energy cost for a 30-day month.

4. What are the conventional methods of forecasting demand? Describe any two of them.  

SECTION – B
There are FOUR questions in this section. Answer any THREE.
The questions are of equal value.

5. (a) With a block diagram explain the operation of a coal fired steam power plant.
(b) Explain briefly the function of superheater, reheater, economizer and air preheater in a steam power plant.

6. (a) What are the advantages and disadvantages of hydro-electric power plant. Explain with a neat sketch the operation of a Kaplan turbine.
(b) A hydro-electric power plant operates under an effective head of 55 m and a discharge of 90 m$^3$/s. Density of water is 1000 kg/m$^3$ and overall efficiency is 85%. Determine the power developed.

7. (a) Explain with appropriate diagram and equation the fission reaction.
(b) Draw the layout plan of a Pressurized Water Reactor (PWR) showing the different components and also explain its working principles.

8. (a) With a block diagram explain the operating principle of an open cycle gas turbine power plant. What are its advantages?
(b) How does the VAR transfer take place between two alternators operated in parallel?
SECTION A

There are FOUR questions in this section. Q. No. 4 is COMPULSORY. Answer any TWO from the rest THREE questions.

1. (a) Two semiconductor materials, Sem-A and Sem-B have identical density of states. Intrinsic carrier concentration of Sem-A is 50 times larger than that of Sem-B at 295 K. Determine the band gap of Sem-A if the band gap of Sem-B is 1.2 eV.
(b) Show that the probability a state $\Delta E$ below the Fermi level ($E_F$) is empty equals the probability a state $\Delta E$ above the Fermi level is filled.

2. (a) Show that the total capacitance per unit area of an Al/SiO$_2$/P-Si MOS capacitor under surface depletion condition can be expressed as:
\[
C = \frac{C_{ox}}{1 + \frac{2e_0^2 \Phi_s}{q N_a e_s t_{ox}^2}}
\]
where the symbols have their usual meaning.
(b) A long intrinsic semiconductor bar is illuminated at the middle as shown in Fig. for Q. 2(b). The whole device remains at room temperature.
(i) Sketch and explain the band diagram of this illuminated semiconductor bar that includes Fermi levels.
(ii) Draw and explain the voltage drop versus position along the length of the sample when a constant current is flown through the semiconductor bar.

Contd P/2
3. (a) A P-type Si is produced with an acceptor doping density of $5 \times 10^{15}$ cm$^{-3}$. During the doping process, some electron trap states are created at an energy level 0.7 eV below the conduction band. Determine the probability of finding an electron in the trap states at a temperature of 300 K. Given:

- band gap of Si, $E_g = 1.12$ eV
- trap states density, $N_t = 5 \times 10^{11}$ cm$^{-3}$
- intrinsic carrier density, $n_i = 1.5 \times 10^{10}$ cm$^{-3}$

(b) Given two semiconductors, A and B, represented by the energy band diagrams shown in Fig. for Q. 3(b). Both the semiconductors have equal electron concentrations in the conduction band. Compare their conductivities with justifications.

![Energy Band Diagrams](image)

Fig. for Q. 3(b)

4. Schematic cross-sectional view of a metal-oxide-semiconductor device is shown in Fig. for Q. 4. Draw approximate energy band diagrams along Z-Z' direction of the structure for (18+17)

(i) Positive gate voltage ($V_G > 0$)

(ii) Negative gate voltage ($V_G < 0$)

![Metal-Oxide-Semiconductor Device](image)

Fig. for Q. 4

Contd .......... P/3
8. (a) A silicon step junction has uniform impurity doping concentration of $N_a = 5 \times 10^{15}$ cm$^{-3}$ and $N_d = 10^{15}$ cm$^{-3}$, and a cross-sectional area of $A = 10^{-4}$ cm$^2$. Let, $\tau_{p_0} = 0.1$ $\mu$s, $\tau_{n_0} = 0.4$ $\mu$s, $\mu_p = 480$ cm$^2$/V-s and $\mu_n = 1350$ cm$^2$/V-s. Calculate:

(i) the ideal reverse saturation current due to holes,
(ii) the ideal reverse saturation current due to electrons,
(iii) the hole concentration at $x = x_n$ if the applied voltage $V_a = 1/2$ $V_{bi}$. [Here, $x_n$ is the depletion width in the n-side and $V_{bi}$ is the built-in potential] and
(iv) the electron current at $x = x_n + L_p$ for $V_a = \sqrt{2} V_{bi}$. [$x_n$, $V_a$ and $V_{bi}$ are as defined above. $L_p$ is the average diffusion length of holes].

(b) A silicon n+p junction is reverse biased at 10 V. Determine the percentage change in

(i) junction capacitance and
(ii) built-in potential

if the doping in the p-region increases by a factor of 2.
EE 413

SECTION – B

There are FOUR questions in this section. Answer any THREE.

Symbols have their usual meanings.

5. (a) Develop the coupled-diode model of a p-n-p transistor.

(b) Sketch the ideal energy-band diagram of a metal-'n' type semiconductor ohmic contact. Explain why this is an ohmic contact.

6. (a) Derive the expressions of built-in potential, electric-field, depletion width and junction capacitance for a linearly graded p-n junction. The doping is symmetrical so that the depletion width in the p-side is equal to that of the n-side.

(b) The built-in potential barrier of a linearly graded silicon p-n junction at 300 K is 0.7 V. The junction capacitance measured at 3.5 V (reverse bias) is $7.2 \times 10^{-9} \text{ F/cm}^2$. Find the gradient of the net impurity concentration. (Assume symmetrical doping profile).

7. (a) Consider a uniformly doped GaAs junction at $T = 300$ K. At zero bias, only 20% of the total space charge region is to be in the P region. The built-in potential barrier is 1.20 V. Given that $n_i = 1.8 \times 10^6 \text{ cm}^{-3}$ and $\varepsilon_{GaAs} = 13.1 \varepsilon_0$. Determine –

(i) doping concentration in the p-side,
(ii) doping concentration in the n-side,
(iii) depletion width in the p-side,
(iv) depletion width in the n-side and
(v) maximum electric-field.

(b) Find the stored charge $Q_p$ as a function of time in the n-region of a long p"-n junction in the forward bias current is switched from $I_{F_1}$ to $I_{F_2}$ at $t = 0$ as shown in Fig. for Q. No. 7(b).

![Diagram](Image)
1. (a) "A sampled data control system is stable if all the poles of the closed loop transfer function $T(z)$ lie within the unit circle of the z-plane. Explain briefly the statement in connection with the analysis in the s-plane. (10)

(b) For the following digital control system find (i) Closed loop transfer function in z-domain (ii) Range of $K$ to make the system stable and (iii) Steady state error for the stable system if the input $r(t) = \left( t + \frac{1}{2} t^2 \right) u(t)$. (25)

\[ C(s) = \frac{3K}{s(s + 3)} \]

\[ R(s) = 3K \]

2. (a) The output response of a second order system to a step input is given by the following equation

\[ y(t) = 1 - e^{-\zeta \omega_n t} \left[ \cos \omega_d t + \frac{\zeta}{\sqrt{1 - \zeta^2}} \sin \omega_d t \right] \]

Derive the expressions for $t_p$, $M_p$ and $t_r$. All symbols have their usual meanings. (18)

(b) For the following system determine the value of 'K' and 'a' such that the system has a damping ratio $\zeta$ of 0.7 and an undamped natural frequency $\omega_n$ of 4 rad/sec. Also obtain the rise time ($t_r$), peak time ($t_p$), maximum overshoot ($M_p$) and settling time ($t_s$) in the unit step response. (17)

\[ R(s) = \frac{K}{s+2} \]

\[ C(s) = \frac{1}{s} \]

Fig. 5. For Q. 1(b)

Fig. 5. For Q. 2(b)

Contd .......... P/2
3. (a) Using the Mason's rule find the $\frac{Y_5}{Y_1}$, $\frac{Y_4}{Y_1}$, and $\frac{Y_2}{Y_3}$ in the following SFG.

(b) Obtain a state space model for the system shown in the following figure.

(c) Define system sensitivity. One small submersible vehicle has a depth-control system as shown in Fig. 3(c). Determine $S_{K_1}$ and $S_K$.

4. (a) What are the purposes of reshaping the root locus? Derive the angle and magnitude condition to sketch the root locus for positive feedback control system and $K < 0$. 

Contd ........... P/3
(b) For the following system design a compensator so that the system can operate with a settling time of 0.435 sec at 1.52% overshoot and with a zero steady state error for ramp input. The uncompensated system has the settling time of 0.87 sec. For the uncompensated system the second-order approximation is valid. Also find the gain $K$ and steady state error for the uncompensated system.

\[
R(s) + E(s) \quad K(s + 1.5) \quad C(s) \\
\frac{s(s + 1)(s + 10)}{s^2 + 10s + 10}
\]

**SECTION – B**

There are FOUR questions in this section. Answer any THREE.

Attach constant M-circles and N-circles (chart) with your answer script.

Attach the Bode log-magnitude plots with your answer script (Q. 5(b)) and wherever necessary.

5. (a) Find steady state error $e_{ss}(t)$ for different types of systems in response to ramp input.

(b) For each unnormalized and unscaled Bode log-magnitude plot shown in Fig. for Q. NO. 5(b), find the system type and find the value of the appropriate static error constant. Please attach the Bode Log-magnitude plots along with the answer script.

(c) For the unity negative feedback system with an open-loop transfer function

\[ G(s) = \frac{K}{(s + 2)(s + 4)(s + 5)} \]

(i) Draw the Bode log-magnitude and phase plots. Please attach the plots along with your answer script.

(ii) Determine the range of $K$ within which the system is stable.

(iii) If $K = 200$ in the system, find the gain and phase margins.

6. (a) For the unity negative feedback system with an open loop transfer function

\[ G(s) = \frac{K}{s(s + 1)(s + 2)(s + 5)} \]

using Routh-Hurwitz criterion,

(i) Find the range of $K$ for stability.

(ii) Find the frequency of oscillation when the system is marginally stable.

(iii) Find the actual location of the closed-loop poles when the system is marginally stable.
(b) State Nyquist stability criterion.

(i) Sketch the Nyquist diagram for the system shown in Fig. for Q. No. 6(b).

(ii) Using the Nyquist criterion, find out whether or not the system in Fig. for Q. No. 6(b) is stable.

7. (a) Consider a network with

\[ G(s) = \frac{s + \frac{1}{\beta T}}{s + \frac{1}{\beta T}}, \quad \beta < 1. \]

"Such a network increases the gain crossover frequency and provides higher phase margin frequency" - Justify your answer with Bode log-magnitude and phase plots.

(b) A unity negative feedback system with an open-loop transfer function

\[ G(s) = \frac{K}{(s + 2)(s + 5)(s + 7)} \]

is operating with a 15% overshoot. Using frequency response method, design a suitable compensator to yield a five fold improvement in steady-state error without appreciably changing the transient response. Also, find the compensated system's forward transfer function.

8. (a) For a unity negative feedback system, show that the locus of the closed-loop magnitude frequency response are called constant M circles. Also, show that the locus of the closed-loop phase frequency response are called constant N circles.

(b) Find the closed loop frequency response of the unity negative feedback control system with open-loop transfer function

\[ G(s) = \frac{10}{s(s + 1)(s + 2)} \]

using the constant M-circles, constant N-circles and the open-loop polar frequency response curve. Please attach the chart of constant M-circles and constant N-circles along with the answer script.
Fig. for Q. No. 5(b)
Constant M-Circles and Constant N-Circles