SECTION A

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

All the symbols have their usual significance.

1. (a) For the motor, load and torque-speed curve shown in Fig. 1(a), find the transfer function \( G(s) = \frac{\theta_1(s)}{E_a(s)} \).

(b) Find closed-loop transfer function for the antenna azimuth position control system shown in Fig. 2 using block diagram reduction method.
(c) State Mason’s rule. Find the transfer function, $T(s) = \frac{C(s)}{R(s)}$, for the system represented in Fig. for Q. 1(c) using mason’s rule.

\[ T(s) = \frac{C(s)}{R(s)} \]

2. (a) The block diagram of the heading control system for the Unmanned Free-swimming submersible vehicle is shown in Fig. for Q. 2(a). A heading command is the input. The input and feedback from the submersible's heading and yaw rate are used to generate a rudder command that steers the submersible. Letting $k_1 = k_2 = 1$, represent the heading control loop in state space.

(b) Represent the electrical network shown in Fig. for Q. 2(b) in state space, where $v_0(t)$ is the output.
In the F-E aircraft, if the open-loop transfer function relating normal acceleration, $A_n(s)$, to the input deflection command, $\delta(s)$, is approximated as,

$$\frac{A_n(s)}{\delta(s)} = \frac{-272(s^3 + 1.92s + 84)}{(s + 14)(s - 1.8)(s + 4.9)}$$

Find the state-space representation in phase-variable form.

3. (a) For the unity feedback control system shown in Fig. for Q. 3(a), (i) design the value of gain $K$, when $\Delta = 5$ so that the system will respond with a 10% overshoot (ii) Design the value of $a$, when $K = 16$ so that the system will respond with a 5% overshoot.

\[ R(s) \rightarrow \frac{K}{s+1} \rightarrow c(s) \]

(b) The transfer function relating pitch angle, $\theta(s)$, to elevator surface angle, $\delta(s)$, for the unmanned Free-swimming Submersible vehicle is

$$\frac{\theta(s)}{\delta(s)} = \frac{-0.125(s+0.435)}{(s+1.23)(s^2+0.226s+0.0169)}$$

Using only the second order poles shown in the transfer function, predict percent overshoot, peak time and settling time.

(c) For the system shown in Fig. for Q. 3(c),

(i) Sketch the root locus

(ii) Find the breakaway and break-in points

(iii) Find the value of $K$ that yields a stable system with critically damped second-order poles.
4. (a) Design a PD controller for the system shown in Fig. for Q. 4(a) to reduce the settling time by a factor of 4 while continuing to operate the system with 20% overshoot.

(b) Determine the range of sampling interval, T, that will make the system shown in Fig. for Q. 4(b) stable.

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

5. (a) Find the range of 'k' and 'a' for which the system shown in Fig. for Q. 5(a) is stable. Use Routh-Hurwitz stability criterion.

(b) Consider the system shown in Fig. for Q. 5(b). Find steady state error for unit step input for this system.
6. (a) Using Nyquist Stability criterion, find the range of \( k \) (if any) for stability of the unity feedback systems with following \( G(s) \)

(i) \[ G(s) = \frac{k(s+2)(s+5)}{(s-3)(s-5)} \]

(ii) \[ G(s) = \frac{k(s+2)}{s^2} \]

(b) Define gain margin and phase margin. Briefly explain how gain margin and phase margin can be obtained from Nyquist Diagram.

(c) Assume you have the Nyquist diagram of a negative feedback system. If the system had positive feedback, how could you find its Nyquist diagram from its negative feedback diagram.

7. (a) The bode magnitude plot of a system's open loop gain, \( G(s) \) is provided in Fig. for Q 7(a). If

\[ G(s) = \frac{k(s+a)(s+b)(s+c)}{s^5(s+d)} \]

Find approximate values of \( k, a, b, c, n, \) and \( d. \)

(b) For a unity negative feedback system,

\[ G(s) = \frac{k}{s(s+3)(s+4)(s+8)} \]

(i) Sketch bode magnitude plot and phase plot using suitable value of \( k. \) [Use semi-log papers and attached them to the answer script]

(ii) Using frequency response technique, find the value of \( k \) to yield 10% overshoot.
8. (a) What are few advantages of using frequency response technique for system design over the root locus method? (5)

(b) Show that M circles are a family of circles which are loci of closed loop frequency response for unity feedback system. (10)

(c) The system shown in Fig. for Q. 8(c) is operating with 15% overshoot. Using frequency response method, design a lag compensator to yield five-fold improvement in steady state error without appreciably changing transient response. (20)
SECTION A
There are FOUR questions in this section. Answer any THREE.

1. (a) All steady state excess electron (or hole) concentration created optically is $2 \times 10^{11}$ cm$^{-3}$ in an n-type Si with $n_0 = 10^{14}$ cm$^{-3}$. Find electron and hole quasi-Fermi level positions relative to $E_F$. (20)

(b) Prove that $\frac{D_p}{\mu_p} = \frac{kT}{q}$, where symbols have their usual meanings. (15)

2. (a) An abrupt Si pn junction has $N_D = 10^{17}$ cm$^{-3}$ on the p-side and $N_A = 10^{16}$ cm$^{-3}$ on the n-side. At 300 K, (i) calculate the Fermi levels, draw an equilibrium band diagram and find $V_B$ from the diagram; (ii) Compare the result from (i) with $V_B$ calculated from analytical expression for $V_B$. (17)

(b) A Si pn junction with cross-sectional area $A = 0.001$ cm$^2$ is formed with $N_A = 10^{15}$ cm$^{-3}$, $N_D = 10^{17}$ cm$^{-3}$.
Calculate:
(i) Contact potential, $V_B$
(ii) Space-charge width at equilibrium
(iii) Current with a forward bias of 0.5 V. Assume that the current is diffusion dominated. Assume $\mu_n = 1500$ cm$^2$/V.s, $\mu_p = 450$ cm$^2$/V.s, $v_n = v_p = 2.5$ $\mu$m.
Which carrier causes most of the current, electrons or holes and why? If you wanted to double the electron current, what should you do? (18)

3. (a) Consider an ideal contact between tungsten and n-type Si doped to $N_A = 10^{16}$ cm$^{-3}$ at $T = 300$ K. Determine the (i) Schottky barrier height, (ii) built-in potential barrier, (iii) peak electric field with an applied reverse-bias voltage of $V_R = 5$ V, (iv) draw the band diagram at thermal equilibrium. Given: $\phi_m = 4.55$ V and $\chi_w = 4.01$ V. (29)

(b) Obtain an expression of junction capacitance per unit area of an n-type Schottky barrier with reverse-biased voltage $V_R$. (15)

4. (a) Using charge neutrality condition obtain an expression for $n_0$ in a Si doped with $N_A$ and $N_D$. For what condition Si can be considered as n-type? (17)

(b) Using the Maxwell-Boltzmann approximation obtain $p_0$ as a function of $E_F$ and $E_p$. (18)
SECTION - B

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

5. Consider a p-type silicon doped to $3 \times 10^{16}$ cm$^{-3}$. The SiO$_2$ has a thickness of 500 Å. An $n'$ polysilicon gate is deposited to form the MOS capacitor. The work function difference $V_{fb} = -1.13$ eV for the system. Consider $T = 300$ K, $\mu_n = 600$ cm$^2$/V-s, $\mu_p = 200$ cm$^2$/V-s. Calculate:
   (i) the thermal conductivity near the Si-SiO$_2$ interface under flat band condition and at inversion
   (ii) the maximum depletion width and the maximum space charge density.
   (iii) the threshold voltage if there is no oxide charge and if there is an oxide charge of $10^{11}$/cm$^2$
   (iv) the substrate bias that will change the threshold voltage from the $V_{fb} = 0$ by 0.4 V.

6. (a) The shift in the flat-band voltage of a MOSFET due to a fixed charge distribution $\rho(x)$ in the oxide is given by $\Delta V_{FB} = \int_{-L/2}^{L/2} \frac{q \rho(x)}{\varepsilon_{ox}} dx$. Calculate $\Delta V_{FB}$ for the following oxide charge distribution:
        (i) $Q_{ox} = 5 \times 10^{11}$/cm$^2$ is entirely located at the oxide-semiconductor interface
        (ii) $Q_{ox} = 5 \times 10^{11}$/cm$^2$ is uniformly distributed through the oxide with a thickness of 750 Å.

(b) Consider a MOS capacitor made on a p-type substrate with doping of $10^{16}$/cm$^3$. The SiO$_2$ thickness is 500 Å and the metal gate is made from aluminum. Calculate the oxide capacitance, the capacitance at the flat band and the minimum capacitance at threshold.

7. (a) One curve of an n-channel MOSFET is characterized by the following parameters:
        $I_{DSS} = 2 \times 10^{-4}$ A, $V_{DS}$ (sat) = 4 V and $V_T = 0.8$ V
        (i) What is the gate voltage
        (ii) What is the value of the conduction parameter.
        (iii) If $V_G = 3$ V and $V_{DS} = 1$ V, determine $I_D$ and $g_m$.

(b) Consider the Ebers-Moll model and let the base terminal be open so $I_B = 0$. Show that when a collector-emitter voltage is applied, we have
    \[ I_C = I_{CEO} - I_{CS} \left( \frac{1 - \alpha_R \alpha_F}{1 - \alpha_F} \right) \]

8. A silicon p$^+$-n-p transistor has impurity concentrations of $5 \times 10^{18}$, $10^{16}$ and $10^{15}$/cm$^3$ in the emitter, base and collector, respectively. The base width is 1.0 μm and the device cross sectional area is 3 mm$^2$. If $V_{BE} = 0.5$ V and $V_{CE} = 5$ V (reverse) calculate,
   (i) the neutral base width
   (ii) the minority carrier concentration at the emitter-base junction
   (iii) the minority carrier charge in the neutral base region.
1. (a) An EM wave is normally incident on the interface of free space and some other lossless dielectric ($\varepsilon = 4$). The interface is marked by the coordinate $z = 0$. The incident electric field is given as $E_i = (1.5x - 2.41)e^{-2x}V/m$.

(i) Calculate the reflection and transmission coefficients.

(ii) Obtain the expressions of the reflected and transmitted E fields.

(iii) Calculate the H fields for both regions.

(iv) Calculate the power density (power flow across unit area) in the region marked by $z > 0$. All quantities are expressed in SI units.

(b) In the figure for Question 1(b), waveshape of the electric field at some reference time ($t = 0$) along the z axis is drawn. The region $z < 0$ is free space and the region $z > 0$ is a lossy dielectric.

(i) What is the frequency of the excited plane wave?

(ii) Determine the propagation constant and intrinsic impedance for region $z > 0$.

(iii) Determine amount of power lost within a volume of cross-section $1m^2$ confined within $0 < r < 4$. All quantities are expressed in SI units.

2. (a) Two parallel, infinite, lossless transmission lines meet at $z = 0$, where they are being fed by another infinite lossless line. Characteristic impedances of these three lines are $Z_1$, $Z_2$, and $Z_3$ respectively.

(i) Write the general expressions for voltage and current waveforms for all three transmission lines. You can assume no reflections for the first two transmission lines.

(ii) Apply appropriate boundary conditions for voltages and currents at $z = 0$.

(iii) Obtain the expression of power being carried by the forward traveling wave in the feeding line. Calculate the fraction of this input power transmitted to each of the lines being fed. Also calculate the fraction of power being reflected back to the feeding line.

(b) A transmission line with a characteristic impedance of $50 \Omega$ and length 45 cm is known to feed a load of $130 - j85 \Omega$ at a frequency of 3 GHz. The dielectric filling of the line has a relative permittivity of 4. To improve the performance of the line, an engineer proposes that the operating frequency should be increased to 10 GHz.
(i) Calculate the magnitude of the reflection coefficient at 3 GHz and 10 GHz. Assume that resistive part of the load is independent of frequency and the (capacitive) reactive part is inversely proportional to frequency.

(ii) Calculate the input impedance as seen by the generator at both frequencies. Use a Smith Chart if required.

(iii) What is the smallest possible value of the reflection coefficient that can be achieved by increasing the frequency?

3. (a) Design a four section balun transformer to match a 50 Ω load to a 150 Ω line.

(b) In order to match a load of 100 + j30 Ω to a 50 Ω transmission line, an engineer proposes installing a shunt short circuit stub right at the load plane and a quarter wave transformer (QWT) between the feeding line and the load. The stub has a characteristic impedance equal to that of the original feeding line. Calculate the minimum length of the stub and the characteristic impedance of the QWT. Use a Smith chart if necessary.

4. (a) Sketch the field lines along xy, yz and zx planes for TEM wave in a parallel plate waveguide. Assume that electric field is y polarized.

(b) A square iron strip of length 0.6 cm is trapped inside a parallel plate waveguide operating in TEM mode. The strip is positioned parallel to the plates of the waveguide. The waveguide dimensions are d = 2 cm and w = 6 cm. The top plate potential has an amplitude of 0.2 V and the dielectric filling has an intrinsic impedance of 185 Ω. Calculate the time averaged power loss in that iron strip if the surface resistivity of iron is given to be 0.06 Ω. Justify any assumptions that you make.

(c) Find the dimensions of a Teflon filled rectangular copper waveguide that fulfills these following design criteria:

(i) It should support no frequency smaller than 9.72 GHz.

(ii) Only one mode should be supported for all frequencies up to 12 GHz. The relative permittivity of Teflon is 2.08.

SECTION-B

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

5. (a) What is a surface wave? Derive the expressions of field solutions for a TM surface wave on a grounded dielectric slab.

(b) The electric field components of TE_{11} mode inside a cubic resonant cavity is given by

\[ E_z = E_x = 0 \]

\[ E_y = A \sin \frac{\pi x}{a} \sin \frac{\pi y}{b} \sin \frac{\pi z}{c} \]
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Could Q. No. 1 (b)

(i) Find the magnetic field components.
(ii) The resonant cavity filled with a material with dielectric constant of 9.0. Find the TE_{11} mode resonant frequency of the cavity for a = 3.0 cm.

6 (a) Radiation intensity of an antenna is given by \( U(\theta) = B \sin^2 \theta \) for \( 0 \leq \theta \leq \pi \). The antenna is radiating a total power of 100 mW.

(i) Find the value of B
(ii) Calculate HPBW and FNBW
(iii) Calculate its maximum gain and maximum effective aperture. Ignore dielectric and conductor losses.

(b) An over the surface receiver antenna is being designed to detect signals from submarines that are situated within a depth of 80 km from the sea surface. The receiver will be situated in a warship hovering and is supposed to detect any signal that lies within a radius of 60 km around the warship. The engineers at Navy suggest for a frequency of 5 MHz. The radio transmitters at submarines have a maximum gain of 8.0 and total transmitted power is 500 W. The receivers are designed to work at a minimum received power of 1 0 \&mu;W. What should be the maximum gain of the receiving antenna? Assume that water has a dielectric constant of 49 and ignore other losses.

7. (a) Calculate the vector potential \( \vec{A} \) for an infinitesimal dipole and obtain the far field expression directly from the vector components of the vector potential. Also, show that maximum directivity of the infinitesimal dipole is 3/2.

(b) Radiation intensities of two different dipole antennas are given by \( U_1(\theta) \) and \( U_2(\theta) \), respectively. If these antennas are excited with currents of same magnitude and their intensities have the same maximum value, prove that:

\[
\frac{D_{1,\theta}}{D_{2,\theta}} = \left( \frac{\int U_1(\theta) d\theta}{\int U_2(\theta) d\theta} \right)^2
\]

Where \( D_{1,\theta} \) and \( D_{2,\theta} \) represent the maximum directivity of the two antennas, respectively.

8. (a) Derive the expression of the array factor of an N element linear array.
(b) Derive the conditions of a broadside array of dipoles that has no maxima along the end fire direction.
(c) Design a 10 element broad side array that has a first null bandwidth of 30°. Roughly sketch the polar plot of array factor clearly showing the nulls, major lobe and minor lobes.
SECTION - A

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

1. (a) Show the process sequence of fabricating an inverter on a NWELL CMOS process. Clearly show the mask used and the device cross-sectional diagram after each step. (20)

   (b) Two resistors each having 4 unit resistors are to be matched in a layout. The sheet resistance varies linearly as a function of position. Between interdigitated layout and common centroid layout which one will you prefer for matching? Justify your answer with numerical values. (15)

2. (a) Show in a diagram the origin and model of CMOS latch up in a PWELL process. How latch up can be prevented? (15)

   (b) Consider designing a control circuit that will swap the contents of two registers R1 and R2 when the control signal w goes to HIGH. You can use another register R3 to temporarily hold the value of one of the registers whose value will be swapped. Draw the state diagram, state table and state assigned table of the Moore type Finite State Machine (FSM) and the circuit diagram of the controller. (20)

3. (a) Using a structured design approach, develop a bus arbitration logic for n-line bus such that access is given to the highest priority line. If priority is given according to ascending order (line N highest priority) draw the circuit and stick diagram of a basic leaf cell. (20)

   (b) Draw the gate level circuit for implementing the function \( f = \overline{A}.B + A.\overline{B} \) using NOT, AND and OR gates. Suppose that you want to detect stuck at 1 faults at all the primary inputs and the primary output. Derive the corresponding minimum set of test vectors. (15)

4. (a) In the Fig. for Q. 4(a), transistor 1 is stuck open (O.). Find all the two pattern test vectors that will detect the fault. (10)
(b) Show the NOR-NOR implementation of a PLA circuit which will provide the following outputs in CMOS logic.
\[ Z_1 = a\overline{b} + c\overline{d} \]
\[ Z_2 = ab \]

(c) Draw the schematic diagram of a scanable D flip-flop built from inverters and CMOS transmission gates.

SECTION - B

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

5. (a) For the connection of the NMOS pass transistor shown in Fig. for Q. 5(a) find the output voltage \( V_{out}, V_{out} \) and \( V_{out3} \). Assume \( V_m = 1 V, V = 0.5 V \).

Contd .... P/3
(b) With necessary figures explain what happens to switching points of transistor characteristics curve and noise margins NM1 and NMH when P/N is increased in a CMOS inverter pair. Assume that the logic levels are selected at the unity gain points of the DC transfer characteristics curve to maximize the noise margin.

(c) If the data is completely random for a 4 input OR gate built out of 2 input NOR and 2 input NAND gates, find the activity factor. Also, find the dynamic power dissipated in the gate, if the clock frequency is 1 GHz, the supply voltage is 1.2 V and the load capacitance is 5 pF.

5. (a) A 3 input CMOS NOR gate is driving h number of similar gates. Draw the schematic diagram of the NOR gate at MOS transistor level. Assume that mobility of electrons is thrice the mobility of holes. Show the aspect ratio of the transistors to achieve equal rise and fall resistance to that of a unit inverter in the worst case. Show the switch level RC model of the NOR gate and calculate the rising propagation delay (t\text{pu}), falling propagation delay (t\text{pd}), and falling contamination delay (t\text{fc}).

(b) Derive the expression for the short circuit dissipation of a CMOS inverter.

7. (a) A buffer chain is to be designed for a clock signal which will drive 1500 logic gates. The input capacitance of each of the logic gates is 8 pF and the output capacitance is 3 pF. The minimum sized inverter in the process has an input capacitance of 4 pF and output capacitance of 2 pF and output capacitance of 2 pF. Find the size (n) and the number of stages (m) of the required buffer chain. You have to derive the equations used in your calculation first.

(b) A 4 bit data path consists of register, ALU and a shifter. Show two possible bus architectures of the system such that an addition operation of two operands stored in the register and storing the result back in the register can be computed in at most two clock cycles.
8. (a) (i) Show the circuit diagram of a 2x2 SRAM array which uses 6 transistors memory cell as basic storage cell. Clearly show the row select, column select, pre-charge and sense signal in your circuit.

(ii) Explain how READ and WRITE operation are performed showing the first row and second column cell as an example.

(iii) Explain how sense amplifier reduces the READ time of the cell.

(b) Draw the selection and control of a 4x4 register array that can select any register for READ or WRITE, can select two registers simultaneously and can READ the contents of a single register to both A and B buses of a two bus architecture system. Briefly explain the operation.
SECTION A

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

1. (a) Determine the input power factor of a single phase full bridge diode rectifier driving a highly inductive load.

(b) A single phase full bridge diode rectifier is supplied from a sinusoidal ac supply of 240 V RMS. The rectifier charges a battery pack of 110 V dc. What should be the series resistance value to limit the average charging current to 10 A? Also determine the power dissipation in the resistance.

2. (a) Draw a single phase full bridge SCR based controlled rectifier circuit and hence explain (with necessary gating signals and input output waveforms) its operation in steady state condition considering continuous conduction mode where the output current is reasonably constant.

(b) A dc motor is controlled through a single-phase full bridge controlled rectifier. Considering negligible armature resistance and brush drops in the motor armature, determine the input supply voltage and firing angle to set the armature voltage to 200 V.

3. (a) Derive the dc output voltage equation of a three-phase full bridge controlled rectifier.

(b) A position control (servo) system uses a three-phase dual converter supplied from a balanced supply with line to line voltage of 415 V (RMS value). What should be the firing angles of the forward and reverse converters if the output voltage is set to ±200 V dc. If one phase is faulty (broken line), what would be new output dc voltage if the firing angles are kept same as before?

4. (a) What are the adverse effects of using phase controlled converters in ac voltage control applications?

(b) With a neat diagram explain the input/output voltage and current waveforms in a single phase ac voltage controller using bi-directional thyristors. Also determine the RMS ac voltage as a function of the input voltage and firing angle.

(c) A single phase cyclo-converter converts 50 Hz to 25 Hz. Determine the firing angle to make the RMS output voltage to 50% of the input supply. Consider resistive load

Contd ............ P/2
5. (a) Find the maximum peak-to-peak ripple current of a step-down dc-dc converter for continuous current flow.

(b) The dc converter shown in fig. for Q. 5(b) has a resistive load of 20 \(\Omega\) and input voltage of 220 V. When converter remains on, its voltage drop is 1.5 V and chopping frequency is 10 kHz. If the duty cycle is 80%, determine (i) the average output voltage, (ii) the rms output voltage, (iii) the converter efficiency, (iv) the effective input resistance, and (v) the rms value of the fundamental component of harmonics on the output voltage.

6. (a) What are the constraints for controllable transfer of energy between two dc voltage sources?

(b) Derive the expression for critical values of the inductance and capacitance in a buck regulator for continuous inductor current flow.

(c) The dc converter shown in fig. for Q. 6(c) is used to control power flow from a dc voltage, \(V_s = 100\) V to a battery voltage, \(E = 220\) V. The power transferred to the battery is 30 kW. The current ripple of the inductor is negligible. Determine, (i) the duty cycle \(K\), (ii) the effective load resistance, and (iii) the average input current.
7. (a) What are the performance parameters of inverters? 
   (b) Discuss the operation of a single-phase full bridge voltage source inverter, and present the switch-states in a table.
   (c) What are the purpose of feedback diodes in inverter?

8. (a) What are the methods of voltage control within the inverter?
   (b) Explain the space vector modulation techniques for voltage control of a three-phase inverter.
   (c) Discuss the operation of series resonant inverter with unidirectional switches.
SECTION-A

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

All symbols have their usual meanings.

1. (a) Define meridional ray and skew ray in optical fiber. For meridional rays, derive the expression relating the numerical aperture and relative refractive index difference between core and cladding of an optical fiber. State the significance of this relationship. (13)

(b) Draw the attenuation spectrum of silica fiber and indicate different low loss windows for optical fiber communication. Also, characterize the 4th generation optical fiber communication system. (10)

(c) A step index fiber has a core diameter of 8 μm and a core refractive index of 1.48. Estimate the range of wavelength of light for single-mode operation when relative refractive index difference is 1.5%. It is required to increase the core diameter to 10 μm while maintaining the single mode operation at the same shortest wavelength. Estimate the maximum possible relative refractive index difference for the fiber. (12)

2. (a) What is optical fiber mode? Define leaky modes and radiation modes. Find the cut-off condition of a mode in a fiber and hence define the normalized frequency. (13)

(b) Draw the plot of normalized frequency for a few low-order fiber modes. Show the single-mode and multimode conditions. (11)

(c) How does PMD occur and how does it affect an optical fiber communication system? (11)

3. (a) Why is cabling necessary? Draw the structure of a stranded loose tube fiber cable with aluminum and steel tape plus non-metallic central strength member. (10)

(b) How is the GVD parameter related to the dispersion parameter? How does the chromatic dispersion affect the data transmission through an optical fiber? Draw the total chromatic dispersion characteristics for various types of single-mode fibers and mention their applications. (15)

(c) A digital single-mode optical fiber system is designed for operation at a wavelength of 1550 nm and a transmission rate of 580 Mbytes over a distance of 50 km without repeaters. The single-mode ILD is capable of launching a mean optical power of -10 dBm into the 

Contd ........ P/2
fiber which exhibits a loss of 0.24 dB/km. In addition, average splice losses are 0.1 dB at 1 km intervals. The connector loss at the receiver is 0.5 dB and at the transmitter 1 dB. The receiver sensitivity is -40 dBm. There is dispersion-equalization penalty of 1.5 dB. Finally, an extinction ratio penalty of 1 dB is predicted for the system. Perform an optical power budget for the system and determine the safety margin.

4. (a) What are the sources of Kerr effects and stimulated scattering effects in an optical fiber? Explain the SRS mechanism and its impact on a multichannel fiber-optic transmission system.
(b) How do the XPM and FWM impair the WDM transmission system? Explain their mechanism also
(c) Write short notes on (ANY TWO):
   (i) PBT star coupler
   (ii) OADM
   (iii) AWG

SECTION-B

There are FOUR questions in this section Answer any THREE.

5. (a) Define population inversion and write the Einstein relation for a lasing action.
(b) Draw the cross-section of an injection laser diode and derive the conditions for laser oscillation.
(c) Compare the following characteristics of and LED and ILD:
   (i) Input-output characteristics
   (ii) Spectral characteristics
Comment on their applications in a fiber optic communication system using SMF and MMF.

6. (a) Briefly explain the mechanism of photo detection in a PIN photodiode. How are the limitations overcome in a PIN photodiode?
(b) Draw the block diagram and equivalent circuit of a direct detection receiver using an APD. Find the noise currents at the receiver output ad the SNR. What are APD excess noise factor and optimum APD gain?
(c) A direct detection optical link is operating with intensity modulated data at a rate of 2.5 Gbps with a PIN photodiode at the receiver. The quantum efficiency of the photodiode is 80% at the operating wavelength of 1310 nm. The pre-amplifier has a load resistance of 150 ohm at a noise temperature of 27°C with a bandwidth equal to data rate. The incident average optical power is 100 μW.
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Contd ... Q. No. 6(e)

Determine:

(i) the rms noise currents at the output
(ii) the SNR at the output of LPF
(iii) the BER of the link.
(Assume erf(x) = e⁻ₓ²)

7. (a) Distinguish between direct and indirect modulators. What is an Mach-Zehnder interferometer (MZI)? What are its application in optical communications? (10)

(b) Discuss with schematic diagram, the principle of operation of an Electro optic phase modulator and MZM. (15)

(c) What is optical PDM (OFDM)? What are its limitations? Why is WDM more attractive than OFDM in an optical communication system? (10)

8. (a) State the merits of an optical amplifier over regenerative repeaters (10)

(b) Discuss the operations of a semiconductor optical amplifier as an SLA and an FPA. (12)

(c) Why is EDFA attractive in a WDM transmission system compared to a SOA? Draw the schematic of an EDFA and briefly explain its operational features. (13)
SECTION - A

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

1. Some points on the band structure of GaAs shown in Fig. for Q. No. 1 are reported in Table for Q. No. 1. Find the following—
   (a) Conductivity effective mass and density of state effective mass for electron.
   (b) Heavy, light and split-off hole effective mass in [1, 0, 0] direction.
   (c) Heavy, light and split-off hole effective mass in [1, 1, 1] direction.
   (d) Bandgap and comment whether the material is direct or indirect band gap material.
   (e) Split-off energy ($E_s$).

   Make necessary assumptions.

2. (a) Suppose a thin layer of $Ga_{1-x}In_xAs$, $n_{Ga}$, sandwiched between two AlAs layer forms a Quantum Well. The structure only allows red light ($\sim$660 nm) to pass through it, in the visible spectrum. The lattice constant of unstrained GaInAs : $P$ is found to be 5.7313 Å. Also, the first Eigen energy for electron in the well is 0.23 eV higher than the confinement band edge and the first eigen energy for hole in the well is 0.1 eV lower than the valence band edge. Using additional information from table for Q. No. 2(a), find—

   (i) Values of $x$ and $y$
   (ii) Critical thickness of GaInAs : $P$ to match its lattice parameter with the substrate.

   To estimate parameters for GaInAs : $P$ you may use the following formula—

   \[ b(x, y) = (1 - x) y b_{Ga} + (1 - x)(1 - y) b_{In} + xy b_{In} + x(1 - y) b_{As} \]

   (b) Briefly discuss the significance of lattice mismatch in semiconductor junctions. Explain how it can be resolved.

3. (a) Draw Energy band diagram of the following metal semiconductor junctions and mention whether it is Ohmic or Schottky

   (i) Al (110) on top of $n$ - GaAs,
   (ii) Cu (111) on top of $n$ - GaAs,
   (iii) Ag (111) on top of $p$ - GaAs,
   (iv) Au (100) on top of $p$ - GaAs.

   If Schottky, then also find the barrier height.
Al, Cu, Ag and Au have work functions 4.06 eV, 4.98 eV, 4.74 eV and 5.47 eV respectively. GaAs has electron affinity of 4.07 eV and bandgap of 1.51 eV.

(b) Fig for Q. No. 3(b) shows the cross section of a HEMT. Draw the approximate band diagram of the structure along the direction AA' using Anderson's rule. For necessary parameters see Table for Q. No. 2(a) and apply Vegard's Law whenever necessary.

4 Write answers to the short questions below:

(a) What happens to emitter injection efficiency if there is a spike in the energy band diagram in the emitter-base junction.

(b) Suggest a solution to prevent dopant diffusion from base for HBT.

(c) Mention one advantage and one disadvantage of ballistic injection in HBT.

(d) How base resistance and base transit time in reduced in HBT? What is the problem of the method?

(e) What is avalanche break down? How can it be reduced?

(f) How saturation offset is minimized in HBT?

(g) What problem a wide band gap collector can pose in HBT? What is the solution?

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,

\[ I_D = I_K \left( \frac{V_{PD}}{V_{PO}} \right)^2 \left( \frac{V_{GS} + V_{TH} - V_D}{V_{PO}} \right)^2 + \frac{V_{DS} - V_{TH}}{P_{PO}} \]

Here, the symbols have their usual meanings.

(b) The n+p junction of a uniformly doped silicon p-channel JFET at T=300 K has a doping concentration of \( N_d = 5 \times 10^{15} \text{ cm}^{-3} \) and \( N_A = 5 \times 10^{15} \text{ cm}^{-3} \). The metallurgical channel thickness is \( a = 0.5 \mu \text{m} \). Determine the internal pinch-off voltage and the pinch-off voltage of the JFET.

6. (a) What is HEMT? Prove that, for an np heterojunction, the expression of total depletion width is given by,

\[ W = \sqrt{\frac{2 \epsilon \epsilon_p (N_{dp} + N_{ap}) V_{th}}{eN_{d}N_{a} (\epsilon_p N_{dp} + \epsilon \epsilon_p N_{ap})}} \]

Here, the symbols have their usual meaning.
(b) Consider an N-Al₃Ga₅As - intrinsic GaAs abrupt heterojunction structure which can be used as HEMT. Assume that the AlGaAs is doped with N₃ = 3 × 10¹⁸ cm⁻³ and has a thickness of 350Å. Let φₚ = 0.89V, ∆EC = 0.24 eV, εₚ = 12.2 ε₀. Determine the value of threshold voltage at 300 K temperature.

7. (a) Discuss the effect of high injection and bandgap narrowing on the characteristics of bipolar junction transistor.

(b) Consider a silicon npn transistor at T = 300 K has the following parameters given in table for Q. No. 7(b). Calculate the emitter-to-collector transit time and the cutoff frequency of a bipolar transistor.

<table>
<thead>
<tr>
<th>Table for Q. No. 7(b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lₑ = 1 mA</td>
</tr>
<tr>
<td>Xₑ = 0.5 μm</td>
</tr>
<tr>
<td>Xₑ = 2.4 μm</td>
</tr>
<tr>
<td>Cₑ = 0.1 pF</td>
</tr>
<tr>
<td>β = 100</td>
</tr>
</tbody>
</table>

8. Consider an N-Al₃Ga₅As and p-GaAs heterojunction with NₑN = 2 × 10¹⁷ cm⁻³ and Nₑp = 5 × 10¹⁷ cm⁻³ has the following parameters given in table for Q. No. 8.

(a) Sketch the band diagram with proper dimension.

(b) How much does the conduction band spike extend above the conduction band edge in the quasi-neutral region on the p-side (i.e. where x > x_p)?

(c) How large a reverse bias must be applied to this junction to move the spike below the conduction band edge in the quasi-neutral region on the p-side?

(d) Grade the interface on the N-side over the minimum width needed to eliminate the spike in the conduction band. Over what distance do you have to grade the composition? Let the grading go from EₑN to Eₑp.

<table>
<thead>
<tr>
<th>Table for Q. No. 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>Electron Affinity (eV)</td>
</tr>
<tr>
<td>Energy gap (eV)</td>
</tr>
<tr>
<td>Conduction band density of states, Nₑ (cm⁻³)</td>
</tr>
<tr>
<td>Valence band density of states, Nᵥ (cm⁻³)</td>
</tr>
<tr>
<td>Relative dielectric constant, εₑ</td>
</tr>
</tbody>
</table>
Table for Q. No. 1

<table>
<thead>
<tr>
<th>Energy (eV)</th>
<th>Energy (eV)</th>
<th>Energy (eV)</th>
<th>Energy (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.4322, 2.512, 3.38)</td>
<td>1.65</td>
<td>1.48</td>
<td>1.48</td>
</tr>
<tr>
<td>(1.1376, 1.916, 1.926)</td>
<td>1.48</td>
<td>1.48</td>
<td>1.48</td>
</tr>
<tr>
<td>(1.37)</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>(2.376, 0.0)</td>
<td>1.15</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>(3.24, 1.46)</td>
<td>1.15</td>
<td>1.15</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Here from second derivative
\[ f_\alpha = \frac{\partial^2 f}{\partial \alpha^2} \]
\[ f_\alpha = \frac{\partial^2 f}{\partial \alpha^2} \]
\[ f_\alpha = \frac{\partial^2 f}{\partial \alpha^2} \]

DOS effective mass \( m^* \)
Conductivity effective mass \( \hbar^2 \)
Symbols have their usual meaning.

Table for Q. No. 2(a)

<table>
<thead>
<tr>
<th>( a (\AA) )</th>
<th>GaAs</th>
<th>AlAs</th>
<th>InP</th>
<th>InAs</th>
<th>GaF</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_F (eV) )</td>
<td>0.519</td>
<td>3.099</td>
<td>1.628</td>
<td>1.628</td>
<td>1.628</td>
</tr>
<tr>
<td>( m_0 )</td>
<td>0.067</td>
<td>0.15</td>
<td>0.067</td>
<td>0.067</td>
<td>0.067</td>
</tr>
<tr>
<td>( \chi (eV) )</td>
<td>4.67</td>
<td>4.3</td>
<td>4.38</td>
<td>4.9</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Figure for Q. No. 3(b)
SECTION-A

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

1. (a) Explain the operation of an open cycle gas turbine plant with a block diagram. What are its advantages and disadvantages?
   (b) What are the components of a diesel electric power plant? Explain its operation with a block diagram. Why is it used indoor?

2. (a) What are the two criteria for capacity scheduling? Prepare a plan for capacity scheduling of 7 units with different thermal efficiency.
   (b) A generation system will have a total capacity of 300 MW. Find the possible forced outage when the capacity is supplied with one unit and two units of 150 MW each. The operating probability of all units is \( P = 0.98 \), and the forced outage probability is \( Q = 0.02 \).

3. (a) Explain with a neat diagram how the steam flow and fuel inputs are controlled when real power varies in a steam power plant.
   (b) How the reactive power (VAR) transfer takes place between two alternators operating in parallel and connected to an infinite bus?

4. (a) What type of hydraulic turbine is used in Kapai hydroelectric power plant? What are the main components of a storage-type hydro plant?
   (b) A hydro-electric power plant operates under an effective head of 50 m and a discharge of 90 m³/sec. Density of water is 1000 kg/m³ and overall efficiency is 90%. Determine the power developed.

SECTION-B

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

5. (a) Explain with diagram the fission reaction and equations how energy is released in a nuclear reaction.
   (b) Explain with diagram, the operating principles of a Pressurized Water Reactor (PWR).

6. (a) Write the general equation for electricity pricing. Explain the merits and demerits of peak responsibility allocation method and non-coincidental demand method of calculating "C" charge.

Contd ............ P/2
(b) A residential consumer uses 340 units of electricity per month. The unit charges for first, second, third, fourth, fifth, and sixth steps are Tk. 3.53, Tk. 5.01, Tk. 5.19, Tk. 6.42, Tk. 8.51, and Tk. 9.93 respectively. Sanctioned load of the consumer is 3 kW. Demand and service charges are Tk. 15.00 per kW of sanctioned load and Tk. 10.00 per month respectively. The value added tax (VAT) is 5% of the bill. Calculate the monthly electricity bill of the consumer. Minimum charge is Tk. 115.00 per month.

7. (a) What are the salient factors for the selection of a non-nuclear steam power plant? Discuss four of them including environmental impacts.
(b) What is load forecasting methods? Explain the mathematical model of a method considering economic parameters.

8. (a) Draw the layout diagram and explain the operation of a coal fired steam power plant.
(b) What are the disadvantages of small power plants compared to large conventional plants?
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

Date: 09/08/2015

L-4/T-1 B. Sc Engineering Examinations 2013-2014

Sub: EEE 451 (Processing and Fabrication Technology)

Full Marks: 210

Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION-A

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

1. (a) Explain the physical reasons why implantation process is better than diffusion. What factors really drive diffusion process? Discuss the vacancy and interstitial models of diffusion, with appropriate figures.

(b) Explain why oxidation rates are quicker in wet condition. Discuss five most useful applications of SiOx in semiconductor fabrication.

(6+5+15)

2. (a) Why dry etching is preferred over wet etching? Explain the RIE etching sequence. How do you control selectivity in a dry and wet etching environment?

(b) Describe two techniques of physical vapor deposition.

(5+10+6)

3. (a) Describe the float-zone method of crystal growth. Explain why this technique is better in minimizing contamination than CZ method.

(b) Explain the two-color pyrometry technique in measuring temperature. A major source of uncertainty in pyrometer is uncertainty in emissivity. Show that, while measuring a water temperature of 1000°C, a pyrometer operating at 5µm produces a 22°C error in temperature for a 5% uncertainty in emissivity. But the same pyrometer, while working in 0.94-0.96 µm range, produces only 4°C temperature error for the same 5% error in emissivity.

(15)

4. (a) What are the main components of a photoresist? Explain their usages. Also explain, in brief, the basic photoresist chemistry and its resolution capability.

(b) Sketch out and mention all the steps necessary to fabricate the feature shown in Fig. 4(b). Use negative photoresist throughout.

(15)

Fig. 4 for Q. 4(b)
There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) What method do you propose to deposit metal on semiconductors? Elaborate on the process. (15)
(b) Explain why contamination-free environment is necessary for semiconductor fabrication facility. (15)
(c) What properties are typically mentioned in a commercially available wafer specification? (5)

6. (a) Describe the recipe of ‘RCA-clean’. (10)
(b) Describe, in detail, the functions performed by a semiconductor package. (18)
(c) What are the functions of hepa-filters in a clean room? (7)

7. (a) What criteria a metal-system must meet in a semiconductor chip? Explain the advantages of Aluminum as a metal to be used for connections in a chip. Also discuss its disadvantages. (6+14=20)
(b) How does the formation of an eutectic point cause problems in shallow junctions? How to avoid this problem? (8)
(c) Briefly explain the thermo compression technique for gold wire bonding. (7)

8. Write short notes on - (35)
(a) ion implantation
(b) Double - patterning
(c) Annealing effect on p-GaN
(d) Hall-effect measurement.
SECTION-A

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

The questions are of equal value.

1. (a) Classify synchronous permanent magnet (PM) motors according to their rotor magnet positions. What are the difference between synchronous permanent magnet AC motors and PM stepper motors?

(b) What are the types of generators used in wind turbine electricity generation? Which of these are most commonly used and why?

(c) Explain the excitation system of an induction generator used in stand-alone wind electricity generation.

2. (a) What is the working principle of magnetohydrodynamic (MHD) generators? Describe the operating principle of an MHD generator with neat diagrams.

(b) What is seeding of ionized gas in an MHD generator? How Hall Effect related current can be related to minimize loss in the electrodes of an MHD generator? Explain.

(c) What are the major mechanical and electrical components of a wind electricity generating system? Give brief description of each component.

3. (a) Differentiate the operation of an universal motor from dc and ac sources in terms of torque-speed and power characteristics. Explain the differences.

(b) Explain the speed control mechanism of a repulsion motor by brush shifting mechanism. How the direction of rotation of a repulsion motor be reversed by brush positions shifting? Explain.

4. (a) Describe the role of static power converters in wind electricity generation for voltage and frequency regulated ac output. Also, describe how peak power can be harnessed from a wind electricity generator having pump load.

(b) Describe the operation of a single phase six stepped multilevel inverter having three full bridge voltage source inverters connected in series. Provide appropriate circuit diagrams and output voltage waveforms.
SECTION-B

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

The figures in the margin indicate full marks.

5. (a) Explain with necessary diagram why a Brushless DC (BLDC) Motor is called an Electronically commutated Motor. (20)
   (b) Derive an equation for the torque developed in a BLDC motor. (15)

6. (a) What are the basic differences between conventional motors and stepper motors? (10)
   (b) What is micro stepping? How stepper motors are classified according to construction and coil excitation? (10)
   (c) Draw a four coil stepper motor and explain its operation for half step and full step motion with necessary excitation pulses and rotor positions. (15)

7. (a) What are the fundamental differences between a Reluctance Motor and a switched Reluctance Motor? (5)
   (b) Draw a drive circuit for a three winding switched reluctance motor and hence explain how the motor produces useful torque. (15)
   (c) Derive an expression for the torque developed in reluctance motor. (15)

8. (a) Draw the characteristics of a photovoltaic panel and explain the need for maximum power point tracking. (10)
   (b) For a grid connected photovoltaic system, show how a switching converter can essentially extract maximum power from the photovoltaic system at any irradiation. (10)
   (c) With a neat diagram explain the construction and operation of a fuel cell. (15)
SECTION-A

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

1. (a) The periodogram may be viewed as the estimate of the power spectrum that is formed using a filter bank of band pass filters. Explain. 

(b) A random process is known to consist of a single sinusoid in white noise 

\[ x(n) = A \sin(\omega_0 n + \phi(n)) + \eta(n) \]

Where the variance of \( \eta(n) \) is \( \sigma^2 \). Suppose that the first three values of the autocorrelation sequence are estimated and found to be 

\[ \gamma(0) = 1; \quad \gamma(1) = \beta \quad \text{with} \quad \beta > 0; \quad \gamma(2) = 0 \]

Use the Pisarenko harmonic decomposition to estimate the variance of the white noise, \( \sigma^2 \), the frequency of the sinusoid, \( \omega_0 \), and the sinusoid power, \( P = \frac{A^2}{2} \).

2. (a) We would like to build a predictor of digital waveforms. Such a system would form an estimate of a later sample (say \( n_0 \) samples later) by observing \( P \) consecutive data samples. Thus we would set 

\[ \hat{x}(n + n_0) = \sum_{k=0}^{P-1} a_k x(n-k) \]

The predictor coefficients \( a_k \) are to be chosen to minimize 

\[ e^2 = \sum_{n=0}^{\infty} [x(n + n_0) - \hat{x}(n + n_0)]^2 \]

Derive the equations that define the optimum set of coefficients \( a_k \).

Use \( \gamma_k(k,l) = \sum_{l=0}^{\infty} \gamma(l) \gamma(n-k-l) \), if necessary.

(b) The estimated autocorrelation sequence of a random process \( x(n) \) for lags \( K = 0, 1, 2, 3, 4 \) are \( \gamma_0(0) = 2; \gamma_0(1) = 1; \gamma_0(2) = 1; \gamma_0(3) = 0.5; \gamma_0(4) = 0 \) Estimate the power spectrum of \( x(n) \) for each of the following cases:

i) \( x(n) \) is an AR(2) process. [Use the Levinson-Durbin recursion to estimate the AR parameters]
ii) \( x(n) \) is an ARMA (1,1) process.

3. (a) The four-channel analysis filter bank of Fig. for Q 3(a), where \( D \) is a 4x4 DFT matrix, is characterized by the set of four transfer functions, \( H_i(z) = X(z)/X(z), 1 = 0, 1, 2, 3 \). Let the transfer functions of the four subfilters be given by 

\[ G_0(z) = 1 + 0.3z^{-1} + 0.8z^{-2}, \quad G_1(z) = 2 - 1.5z^{-1} + 3.1z^{-2}, \]

\[ G_2(z) = 4 - 0.9z^{-1} + 2.3z^{-2}, \quad G_3(z) = 1 + 3.7z^{-1} + 1.7z^{-2}. \]

Contd ...... \( \ldots F/2 \)
i) Determine the expressions for the four transfer functions, $H_0(z)$, $H_1(z)$, $H_2(z)$, and $H_3(z)$.

ii) Assume that the analysis filter $H_2(z)$ has a magnitude response as indicated in Fig. for Q 3(a2). Sketch the magnitude responses of the other three analysis filters.

(b) An efficient structure for implementing decimators and interpolators is the so-called poly-phase structure. Show that the poly-phase filter implementation of an interpolator can be obtained using a commutative model. Assume that the anti-imaging filter is an FIR filter.

4 (a) State the properties of wavelet and its scaling functions and then define the forward and inverse CWT and DWT.

(b) Derive the expressions of the inter scale relationship of forward DWT expansion coefficient for a discrete-time signal $x(k)$ and show their multirate implementation. Make assumptions as necessary.

(c) Let an ideal low pass filter $H(z)$ with a cut-off at $\frac{\pi}{M}$ be expressed as

\[ H(z) = \sum_{n=0}^{M-1} z^{-n} H_n\left(z^M\right) \]

Show that each poly phase subfilter $H_n(z)$ is an all pass filter.
There are FOUR questions in this section. Answer any THREE.

5. (a) Draw the schematic diagram of an adaptive beam former and briefly describe its principle of operation.

(b) Consider the following system identification problem:

\[ H(z) = 3 + 2z^{-1} \]

The stationary white noise process \( w(n) \) with zero mean and variance 1 is used to identify the LTI system \( H(z) = 3 + 2z^{-1} \). The sensors are not ideal: \( F_1(z) = F_2(z) = z^{-1} + 0.1z^{-2} \). The additive noise, which is uncorrected with \( w(n) \), is also a stationary white noise process with zero mean and variance 0.1. The adaptive filter \( C(z) \) has two coefficients. Determine the optimal coefficient vector \( \theta_{opt} \) for the filter \( C(z) \) in the sense of a minimum mean-squared error.

(c) What is the advantage of an adaptive filter over a Wiener filter?

6. (a) Consider an auto regressive (AR) process of order one, described by the difference equation

\[ u(n) = -au(n-1) + v(n) \]

where \( a \) is the AR parameter of the process and \( v(n) \) is a zero mean white noise of variance \( \sigma_v^2 \). Set up a linear predictor of order one to compute the parameter \( a \). Use the method of steepest descent for the recursive computation of the Wiener solution of the parameter \( a \).

(b) The LMS algorithm is used to implement a dual input, single weight adaptive noise canceller. Set up the equations that define the operation of this algorithm.

(c) Derive the update equation of the normalized LMS algorithm.

7. (a) Consider a correlation matrix

\[ \Phi(n) = u(n)u^H(n) + \delta I \]

Where \( u(n) \) is a tap input vector and \( \delta \) is a small positive constant. Use the matrix inversion lemma to evaluate \( P(n) = \Phi^{-1}(n) \).

(b) What is the algorithmic difference between RLS and LMS update equation? Based on this difference, discuss the advantage of RLS over LMS.
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Contd... O. No. 7

(c) An analog signal \( x(t) \) is band limited to the range \( 900 \leq F \leq 1100 \) Hz. It is used as an input to the system shown below.

\[
\begin{align*}
F_x &= \frac{1}{T_x} = 25 \text{Hz} \\
\text{H}(\omega) &= \cos(\omega \theta_T) \\
\end{align*}
\]

Hence, \( H(\omega) \) is an ideal low pass filter with cutoff frequency \( F_c = 125 \) Hz. Determine and sketch the spectra for the signals \( x(n) \), \( w(n) \), \( v(n) \) and \( y(n) \). Assume arbitrary spectral shape for \( x(n) \).

8. (a) Develop an expression for the output signal \( y(n) \) as a function of the input \( x(n) \) for the multirate structure given below.

\[
\begin{align*}
x(n) &\rightarrow e^{-\frac{n}{2}} \downarrow 2 \uparrow 4 \downarrow 3 \rightarrow y(n)
\end{align*}
\]

(b) Determine the computational complexity of a single-stage interpolator to be designed to increase the sampling rate from 480 Hz to 24 kHz. The interpolator is to be designed as an FIR filter with a pass band edge at 190 Hz, a pass band ripple of 0.002 and a stop band ripple of 0.002. To estimate the order of the filter, you may use Kaiser’s formula:

\[
N = \frac{-20 \log_{10}(\text{ripple}) - 13}{14.6(\omega_s - \omega_p)/2\pi}
\]

Develop a two-stage design of the above interpolator and compare its computational complexity with that of the single-stage design.

(c) Analyze the structure given below and determine its input-output relations. Comment on your results.

\[
\begin{align*}
x_1(n) &\rightarrow \uparrow 2 \rightarrow y_1(n) \\
x_2(n) &\rightarrow \uparrow 2 \rightarrow y_2(n)
\end{align*}
\]