The flyback converter depicted in the figure below has the following parameters: $V_{in} = 24 \text{ V}$, $V_o = 36 \text{ V}$, $N_1 = 30$, and $N_2 = 27$. Given the diode current waveform, (a) (60 points) sketch the rest of the signals. The y-axis of each trace should be labeled with the corresponding numerical values. (b) (20 points) Find the output power. (c) (20 points) Find the average value of the current drawn from the source.
A silicon dioxide film of total thickness 0.8 µm is grown after a two-step thermal oxidation process on a <100> wafer in wet oxygen. The linear growth rate constant (B/A) and the parabolic growth rate constant (B) in this process condition are 2.895 µm/hr and 0.529 µm²/hr, respectively.

How long does it take to grow the initial oxide films and the additional oxide film in each step? The final thickness after the step 1 becomes the initial thickness of the step 2. Assume that the initial thickness in the step 1 is zero. Fill out the three answers in the table based on the formula below.

\[
\tau = \frac{X_i^2}{B + X_i / (B/A)} \quad \quad \quad t = \frac{X_o^2}{B + X_o / (B/A)} - \tau
\]

<table>
<thead>
<tr>
<th>Step</th>
<th>Initial thickness</th>
<th>Final thickness</th>
<th>Time for initial thickness</th>
<th>Time for additional thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0 µm</td>
<td>0.4 µm (after step 1)</td>
<td>( 0.0 ) hour</td>
<td>( ________ ) hour</td>
</tr>
<tr>
<td>2</td>
<td>0.4 µm</td>
<td>0.8 µm (after step 2)</td>
<td>( ________ ) hour</td>
<td>( ________ ) hour</td>
</tr>
</tbody>
</table>

Step 1:

Step 2:
The crosstalk between weekly coupled circuits is described by the following formulas in frequency domain:

\[
\frac{V_{ne}}{V_s} = j\omega \left( \frac{R_{ne}}{R_{ne} + R_{fe} \cdot R_s + R_l} + \frac{R_{ne} R_{fe}}{R_{ne} + R_{fe} \cdot R_s + R_l} \right) \cdot \frac{R_m}{L_m + \frac{1}{C_m}}.
\]

\[
\frac{V_{fe}}{V_s} = j\omega \left( -\frac{R_{fe}}{R_{ne} + R_{fe} \cdot R_s + R_l} + \frac{R_{ne} R_{fe}}{R_{ne} + R_{fe} \cdot R_s + R_l} \right).
\]

The formulas relate the voltages at the near- and far-end ends of the victim circuit \( V_{ne}, V_{fe} \) to the source voltage in the aggressor circuit \( V_s \), source and load resistances in the aggressor circuits \( R_s, R_l \), near- and far-end resistances in the victim circuit \( R_{ne}, R_{fe} \), and the coupling capacitance \( C_m \) and mutual inductance \( L_m \).

The measurement of the near- and far-end voltages induced in two circuits are performed in time domain. Both circuits can be described by a schematic in fig. 1. The only difference between the circuits is the values of capacitance and mutual inductance.

![Schematic diagram of the circuits under test.](image)

In both measurements the source in the aggressor circuit produced the signal presented in fig. 2.

However, the crosstalk waveforms in two circuits are different. The induced voltages for the circuit 1 are given in fig. 3, and for the circuit 2 – in fig. 4.

You are asked to do the following:

**Task1.** Determine the dominant coupling mechanism and the value of the corresponding element (capacitor or inductor) for each circuit.
**Task 2.** Calculate the amplitude and sketch the waveforms of the near- and far-end voltages for circuits 1 and 2 if $V_x$ is a sinusoid signal with the amplitude 1 V and frequency 1 GHz.

![Signal produced by the aggressor source](image1)

**Fig. 2.** Signal produced by the aggressor source

![Crosstalk voltages in circuit 1.](image2)

**Fig. 3.** Crosstalk voltages in circuit 1.

![Crosstalk voltages in circuit 2.](image3)

**Fig. 4.** Crosstalk voltages in circuit 2.
A microstrip patch antenna can be modeled as a rectangular cavity with perfect electric conducting (PEC) top and bottom walls and perfect magnetic conducting (PMC) side walls as shown below. Let the dimension in the $x$ direction be $a$, and the dimension in the $y$ direction $b$.

![Diagram of a microstrip patch antenna with PEC and PMC walls.]

The cavity is typically thin so that there is only a $z$-component of the electric field, and the field can be considered constant in the $z$ direction (hence, $\frac{\partial}{\partial z} \to 0$). The cavity modes are $TM_z$ and can be determined from

$$\vec{E} = \hat{z} \psi(x, y)$$

Then:

a. Write the wave equation for $\psi(x, y)$

b. Write the solution for $\psi(x, y)$

c. Write the boundary conditions explicitly

d. Apply the boundary conditions and give the solution for $\vec{E} = \hat{z} \psi(x, y)$

e. Write the dispersion relation

f. Determine the modal cut-off frequencies (what is the lowest order mode?)
The dynamical equations of a nonlinear control system are given by

\[
\begin{align*}
\dot{x}_1(t) &= -\left(x_1(t)\right)^3 + \left(x_2(t)\right)^2 + x_1(t)u(t), \\
\dot{x}_2(t) &= \left(x_1(t)\right)^2 - \left(x_2(t)\right)^3 + x_2(t)u(t),
\end{align*}
\]

where \(x_1\) and \(x_2\) are the state variables, and \(u\) is the input variable.

(a) Determine all the equilibrium states of the system. \hspace{1cm} (40%)

(b) Check the local stability of the system using Lyapunov’s First Stability Theorem for all the equilibrium states. \hspace{1cm} (60%)
(a) Given the diagram above, show that:
   (i) The transfer function of the zero-order hold (ZOH) is \( \frac{1-e^{-sT}}{s} \)
   (ii) Given the result of part (i), derive an expression for the pulse transfer function, \( G(z) = \frac{Y(z)}{R(z)} \)

(b) For the following system

Suppose \( G(z) = \frac{(1-e^{-1})z}{z-e^{-1}} \) and \( D(z) = \frac{z-0.5}{z+0.3} \)

(i) Find the closed-loop transfer function.
(ii) Determine the range of \( K \) for which the system is stable. If you have problems with the numerical solution of this part, at least give the equation to be solved for \( K \) (for partial credit)
Consider the closed-loop system with

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

Design a lead compensator to achieve damping coefficient \( \zeta \approx 0.707 \) and 2\% settling time \( T_s=2 \) sec.
The transmitted signal of Amplitude Modulation (AM) systems is defined as

\[ x(t) = A[1 + k \cdot m(t)] \cos(2\pi f_c t) \]  

(1)

where \( A \) is the constant gain, \( k \) is the modulation index, \( f_c \) is the carrier frequency, and \( m(t) \) is the information signal with zero mean and power \( P_m \).

1. Find the mean and power of the transmitted signal \( x(t) \).

2. Consider \( m(t) \) as the input and \( x(t) \) as the output. Is the modulation scheme a linear time-invariant system? Why?
A random process $x(t) = e^{at}$ is a family of exponentials depending on the random variable $a$. Assume that the probability density function (pdf) of $a$ is $f_a(a)$. Find the mean $\mu_x(t)$, the autocorrelation $R_{xx}(t_1, t_2)$, and the first-order pdf $f(x, t)$ of $x(t)$.