Consider the simplified distribution feeder shown below. The short-circuit positive/negative and zero sequence reactances for the equivalent source are \( j0.2 \) and \( j0.6 \) pu (on a 50 MVA base) respectively. The positive/negative and zero sequence reactances of line B-C are \( j0.35 \) and \( j1.0 \) pu (on a 4600 V, 50 MVA base) respectively. A solid single-line-ground fault occurs on bus C. Compute the line-ground and line-line voltages at buses A, B, and C.
You are designing a grid-tied PV system. You must use a PV panel with the following specifications at STC (1 kW/m², 25°C):

- Open-circuit voltage: 29.6 V
- Short-circuit current: 8.25 A
- Maximum power point voltage: 26.3 V
- Maximum power point current: 8.00 A
- Voltage temperature coefficient: -0.3%/°C

The inverter has the following specifications:

- 4 kW input
- Maximum power point tracking voltage range: 180-520 V
- Absolute maximum input voltage: 600 V

The system will be installed in an area with a temperature range of -10°C to +50°C.

a. Determine the best configuration of PV panels that maximizes the power production without violating any inverter specifications.

b. Other inverters are available with identical voltage ratings, but various power ratings. Design an array that will deliver between 7 kW and 8 kW with an appropriate inverter.

c. List five important considerations for system design that will ensure that you meet the National Electrical Code (NEC). For each consideration, identify whether it is applicable to any generic electrical installation or it is specific to this kind of system.
Problem A.3

Power/Machinery

For the full-bridge dc-dc converter depicted in the figure below assume that:
1) The analysis is performed in steady-state.
2) The converter operates in continuous conduction mode (CCM).
3) The components are ideal.

If $V_{in}=40$ V, $d=0.4$, $N_2/N_1=8$, $L=60$ μH, $R=10$ Ω, and switching frequency $(1/T)=100$ kHz determine:
a) (30 pts) the output voltage ($V_o=?$),
b) (30 pts) the average diode voltage ($<V_{D2}>=?$),
c) (10 pts) the average inductor current ($<i_L>=?$),
d) (20 pts) sketch switch voltage $V_{SI}$, and
e) (10 pts) the maximum switch voltage ($V_{SI,max}=?$).
An electric vehicle which is being driven on a level road has the following parameters:

Speed = 50 miles/hour (1 mile = 1609 m)

Resistive Force (in Newton) = 177+0.118*m; where m is the vehicle mass

Vehicle mass = 1317 kg (battery pack excluded)

Specific Energy of the NiMH batteries used = 70 Wh/kg

a) Find the amount of energy needed to drive this vehicle for an hour (exclude the battery mass)

b) How much battery (in kg) is needed?

c, d) Add the battery mass to the vehicle mass and redo parts a and b.
Problem: A5  Area: Circuits/Electronics  Code #: 

Many RF amplifiers use enhancement FETs. These need a negative gate voltage. If the gate voltage is 0V and a drain voltage is applied the transistor will certainly be destroyed. Power sequencing is needed to prevent this.

Assume you have a

- A somewhat not so stable +10V source. It may vary from 9 to 11V
- A stable -5V source

And your RF amplifier needs +5V at 1A at the drain and -3V at 1mA at the gate.

You need to ensure:

1) During turn on: No drain voltage is applied if the gate voltage is between 0 and -2V.
2) During turn off or supply failure: If the -5V supply fails and its voltage drops (mathematically: increases) from -5V to -4V the +5V needs to be turned off

Design a circuit that fulfills the requirements. For each resistor and capacitor explain how you derived or estimated its value.

Explain how the circuit achieves:

a) Providing a stable 5V output from a 10V source
b) During turn on, ensuring that the gate voltage is at -2V before +5V is engages
c) During turn off, ensuring that the +5V is turned off when the negative supply is at (mathematically) larger than -4V.
Someone has designed a buck converter for the following specifications: input voltage 12 V, output voltage 3.3 V, output current 10 A, inductor current ripple less than or equal to 2 A (peak-to-peak), output voltage ripple less than or equal to 33 mV (peak-to-peak). The designer chose an inductance of 33 μH and an output capacitance of 1000 μF. The capacitor has an ESR of 20 mΩ.

a. Determine the operating duty ratio
b. Determine the switching frequency that would meet the ripple current specification.
c. Determine the relationship between inductor current ripple and output voltage ripple. If you make an approximation, defend it.
d. Determine the switching frequency that would meet the ripple voltage specification.
Consider an active RC filter shown in the fig. below.

![Active RC Filter Diagram]

The amplifier AMP1 has a voltage gain of $K_0$, infinite input impedance and zero output impedance.

1) Derive the expression for the frequency response of the filter $K(j\omega) = \frac{U_{out}(j\omega)}{U_{in}(j\omega)}$.

2) Assuming $R_1=R_2=R$, $C_1=C_2=C$, $K_0=2.5$, sketch the magnitude of the frequency response $|K(j\omega)|$. Determine the type of the filter (low-pass, band-pass, etc.).

3) Assuming $R_1=R_2=R$, $C_1=C_2=C$, determine the maximum gain of the filter $(\max(|K(j\omega)|))$ when $K_0=2.5$, and $K_0=3$. Explain the results.
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 films 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.

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

<table>
<thead>
<tr>
<th></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>Step 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>Step 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:
Problem: A11  Area: Fields and Waves  Code #:

The problem relates to the effect of parasitics on the ability to measure the nominal capacitance value at the given frequency. Please explain the difficulties in measuring the following capacitances at the given frequency.

Given is a capacitor of size 0804 (2mm long 1mm width and 1mm height) mounted on a typical 4 layer PCB having about 0.5 mm distance between planes. Assume 100mΩH as the (series) ESR value of the capacitor. Assume it is not frequency dependent.

1) What is the typical ESL (effective series inductance) value of the capacitor in a typical PCB mounted situation? Show a typical mounting situation and sketch the current loop that defines the inductance.

ESL:

Sketch:

2) Convert the equivalent circuit from a series circuit to a parallel circuit for the following cases:

100pF 10MHz:

0.1pF 1kHz:

1μF 1kHz:

1μF 100MHz:

Mathematically, the circuits are equivalent at any given circuit. However, at a given frequency and value combination one circuit maybe more physically intuitive in describing its behavior in the circuit. Explain in which case the parallel circuit is more intuitive, and explain why.
3) Is it easy to measure the nominal capacitance value for $100\text{pF}$ at $10 \text{ MHz}$? Explain if the parasitics will make this measurement difficult or easy. It maybe good to calculate the impedances of the parasitics at this frequency to understand potential difficulties in the measurement.

4) Is it easy to measure the nominal capacitance value for $0.1\text{pF}$ at $1 \text{ kHz}$? Explain if the parasitics will make this measurement difficult or easy.

5) Is it easy to measure the nominal capacitance value for $1\text{uF}$ at $1 \text{ kHz}$? Explain if the parasitics will make this measurement difficult or easy.

6) Is it easy to measure the nominal capacitance value for $1\text{uF}$ at $100 \text{ MHz}$? Explain if the parasitics will make this measurement difficult or easy.
Problem: A12  
Area: Waves, Devices, & Optics  
Code #:_____.

A uniform plane wave travelling in free space is incident normally upon a lossless dielectric medium with a relative permittivity of 4.0 as shown in the figure. If the incident electric field is given by

$$E^{inc} = E_0 e^{-j k_0 x}$$

where $k_0 = 0.5\pi, E_0 = 120\pi$.

![Diagram of wave interface](image)

Write

1) The frequency of the electromagnetic wave and wavenumber in the dielectric medium.
2) The corresponding incident magnetic field.
3) The reflection and transmission coefficients by boundary conditions on the interface ($z = 0$).
4) The incident, reflected and transmitted power density.
5) The equivalent electric and magnetic currents on the interface ($z = 0$).
6) Using the equivalence principle and radiated fields by electric and magnetic currents given in 5) to calculate the radiated fields in the regions of the free space ($z < 0$). Prove the reflection coefficient by this method is same to those obtained in 3).

Important note: The following integral may be used

$$\int_{x'=-\infty}^{\infty} \int_{y'=-\infty}^{\infty} \frac{\exp(-jk|\mathbf{r} - \mathbf{r}'|)}{|\mathbf{r} - \mathbf{r}'|} d\mathbf{x}' d\mathbf{y}' = \int_{\phi'=-\pi}^{\pi} \int_{\rho'=-\infty}^{\infty} \frac{\rho' \exp(-jk\sqrt{(\rho')^2 + (z-z')^2})}{\sqrt{(\rho')^2 + (z-z')^2}} d\rho' d\phi'$$

Furthermore

$$\lim_{\rho' \to \infty} \{\exp(-jk\sqrt{(\rho')^2 + (z-z')^2})\} \to 0$$

In the lossy medium. The lossless case can then be assumed to have the same behavior.
Consider the system defined by $x(k+1) = Ax(k) + Bu(k), y(k) = Cx(k), u(k) = K_o r(k) - Kx(k)$, where

$$A = \begin{bmatrix} 0 & 1 \\ -0.16 & -1 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, C = [1 \ 0].$$

(a). Design a control system such that the closed-loop poles of the characteristics equation are at:

$z_1 = 0.5 + j0.5, z_2 = 0.5 - j0.5$. (50%)

(b). Determine the gain constant. (50%)
Consider the following continuous-time control system

\[
\begin{bmatrix}
\dot{x}_1 \\
\dot{x}_2
\end{bmatrix} = \begin{bmatrix}
0 & 1 \\
-1 & 0
\end{bmatrix}\begin{bmatrix}
x_1 \\
x_2
\end{bmatrix} + \begin{bmatrix}
0 \\
1
\end{bmatrix}u, \quad y = \begin{bmatrix}
1 & 0
\end{bmatrix}\begin{bmatrix}
x_1 \\
x_2
\end{bmatrix}.
\]

(a) Determine whether or not the system is controllable and observable. (20%)
(b) Obtain the discrete-time state representation in terms of the sampling interval T. (50%)
(c) Determine the discrete-time controllability and observability matrices. (15%)
(d) Find the value of T for which the discrete-time system is controllable and observable. (15%)
A continuous-time linear control system is described by
\[
\dot{x}(t) = \begin{bmatrix}
-10 & -16 \\
1 & 0
\end{bmatrix} x(t) + \begin{bmatrix}
1 \\
0
\end{bmatrix} u(t),
\]
and \( y(t) = \begin{bmatrix}
1 & 8 \\
1 & 0
\end{bmatrix} x(t), \) where \( u, x, \) and \( y \) are the input, the state, and the output variables, respectively.

i. Design a state-feedback control \( u(t) = K x(t) \) where \( K \) is the feedback gain, such that the system is critically damped, and the 5% settling-time is about 1 second. \( (50\%) \)

HINT: The 5% settling time \( t_{5\%} = \left( \frac{3}{\sigma_0} \right) \) for a second-order system with no zero and the poles at \( -\sigma_0 \pm j\omega_0 \).

ii. Assuming that only the output is available; design a feedback controller, such that the system is critically damped, and the 5% settling-time is about 1 second, if possible \( (50\%) \)
A control system is described by
\[
\dot{x}(t) = \begin{bmatrix} -2 & -8 \\ -2 & -2 \end{bmatrix} x(t) + \begin{bmatrix} 2 \\ 1 \end{bmatrix} u(t)
\]
and
\[
y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} x(t)
\]
where \( u, x, \) and \( y \) are the input, the state, and the output variables, respectively.

a) Determine the transformation that transforms the system into the observer canonical form and obtain the observer canonical form. Show your work clearly. \( (60\%) \)

b) Determine the transformation that transforms the system into the controller canonical form and obtain the controller canonical form. Show your work clearly. \( (40\%) \)
A system has two connections, labeled as \( x(t) \) and \( y(t) \). When I treat \( x(t) \) as the input and \( y(t) \) as the output, I know the system is linear, time invariant and stable. The impulse response of the system is \( h(t) \) and it's frequency response is \( H(f) \).

Now suppose the same circuit is used, but I treat \( y(t) \) as the input and \( x(t) \) is the output. What can you tell me about the impulse response and frequency response of the system when it is used in this manner, in terms of \( h(t) \) and \( H(f) \) mentioned above?
An all-pass system's transfer function can be written as

\[ H_{\text{ap}}(z) = \prod_{k=1}^{p} \frac{P_k - z^{-1}}{1 - P_k z^{-1}}. \]

Show that any causal pole-zero system \( H(z) \) that has no poles or zeros on the unit circle can be expressed as

\[ H(z) = H_{\text{min}}(z) H_{\text{ap}}(z) \]

where \( H_{\text{min}}(z) \) is minimum phase (all poles and zeros within the unit circle).
An FM-modulated signal $x(t)$ has the form

$$x(t) = A \cos \left[ 2\pi f_0 t + 2\pi f_d \int_0^t m(\lambda) d\lambda \right],$$

where the frequency deviation constant $f_d = 10$ Hz/Volt, and carrier frequency $f_0 = 1$kHz. The input message is $m(t) = A_m \cos(2\pi f_m t)$, where $A_m = 2V$, and $f_m = 100$ Hz.

1. Derive the complex equivalent baseband representation of $x(t)$. What are the in-phase and quadrature components of the equivalent baseband signal? What are the envelop and phase of the equivalent baseband signal?

2. Sketch the waveforms of the message signal $m(t)$ and the modulator output $x(t)$ for $t = 0$ to $t = 30$ms. Clearly mark all parameters.

3. Sketch the block diagram of a non-coherent FM receiver (demodulator). Specify all parameters in the receiver.

4. Assume the communication is corrupted by an Additive White Gaussian Noise (AWGN) $n(t)$ having a two-sided power spectrum density $N_0/2$. Derive an expression for the demodulated output $y(t)$.
Let \((X, Y)\) be the Cartesian coordinate of mobile users within a coverage area of a cell-phone base station. Assume \(X\) and \(Y\) are independent Gaussian random variables with zero mean and unit variance. Let \(W = \sqrt{X^2 + Y^2}\) and \(\Theta = \tan^{-1}(Y/X)\).

1. Find the joint pdf of \(W\) and \(\Theta\).
2. Find the marginal pdf of \(W\) and the marginal pdf of \(\Theta\).
3. Are \(W\) and \(\Theta\) independent?
4. Find the value of \(r\) for which the probability that \((X, Y)\) falls inside a circle of radius \(r\) is 1/2.
5. Find the conditional pdf of \((X, Y)\) given that \((X, Y)\) is not inside a circle of radius \(r\).