For the 4.16 kV feeder shown above and the time-current characteristics of the recloser and fuse diagram given on the next page and the following coordination settings:

Assume the following recloser settings:
- No intentional time delay
- Two fast and two delayed operations
- First reclose interval = 0.25s
- Second reclose interval = 1s
- Reclose intervals after a delayed trip = 2s
- The fuse clears the fault

A three-phase to ground permanent fault occurs at the end of lateral L1.

Sketch the current profiles as seen by the (1) customers downstream of the fuse of lateral L1 and (2) the recloser.
Problem A.2 Power/Machinery

Two generators have the following fuel costs functions:

\[
\begin{align*}
P_1 & \quad 4 \quad 8 \quad 12 \quad 160 \quad 240 \quad MW \\
P_2 & \quad 6 \quad 11 \quad \quad 100 \quad 250 \quad MW
\end{align*}
\]

Determine the optimal generation scheduling of \( P_1 \) and \( P_2 \) if the system load is 400 MW.
The reference and carrier signals of a single-phase inverter with bipolar switching scheme are depicted in the figure below.  

a) What value has been used for $m_f$ (frequency modulation index)?  
b) If $V_{in} = 100 \text{ V}$, accurately plot the waveform of the output voltage ($V_{in}$ is the dc sources that feeds the inverter).  
c) Find the rms value of the output voltage.  
d) If $V_s = 80.8 \text{ V}$, find the total harmonic distortion (THD) in the output voltage.  
$V_s$ is the amplitude of the fundamental harmonic in the output voltage.
In rush current limiting circuit

If a circuit is plugged into a connector (see drawing "connector") while the 14V DC is on the 470µF capacitor will be charged very quickly. This can overload the 14V supply, and cause a voltage drop in the 14V. Other circuits that need the 14V might fail operating as a consequence of the voltage drop.

Below is a circuit limiting the inrush current. After the 470µF are charged up, the 10 Ohm will determine the current.

a) What is the function of Q2?
b) What is the function of R2?
c) What is the function of R1?
d) What is the function of Q1?
e) Derive the value of current at which the circuit will limit. Use reasonable assumptions, name your assumptions.
f) If the FET Q2 fails (as a drain source short) why will Q1 be destroyed?
For the rectifier depicted in the figure, **A)** Sketch the waveform of the output voltage, **B)** Sketch the waveform of the SCR voltage, and **C)** Find the rms value of the output voltage.
Problem: A10  Area: Waves, Devices, & Optics  code #: _______________________

1. Answer the following questions about a p-n junction diode shown below.

(a) (30%) Make a possible flowchart for fabricating this structure starting from a clean n-type silicon substrate. Adopt the following five items only: (1) oxidation, (2) photolithography (ignore the last step of photoresist stripping), (3) etching (etching is done before the photoresist stripping step of photolithography), (4) diffusion, (5) metal deposition. (exemplary answer: (1) > (3) > (5) > (3) > (2) > (1) > ...... )

(b) (30%) Sketch the pattern of each photomask assuming the negative photoresist process. Clearly indicate the black and transparent areas (as shown in the example).

(c) (15%) Identify the purpose of each photomask.
   - Photomask #1:
   - Photomask #2:
   - Photomask #3:

2. (25%) Answer the questions about traditional optical photolithography systems based on the following information.
   - F = 0.5 x (λ / NA)  (F: minimum feature size (i.e. resolution) [μm], λ: wavelength [μm], NA: numerical aperture)
   - DF = 0.6 x (λ / NA²)  (DF: depth of focus [μm])

(a) What wavelength is required to achieve F = 0.25 [μm] with NA = 1.0?

(b) What is the value of DF corresponding to your value of NA?

(c) Changing the wavelength (λ) of the illumination source is preferred rather than changing the numerical aperture (NA). Briefly explain why (a couple sentences).
Problem: A11   Area: Fields and Waves   Code #:

In a coax cable multiple impedances can be defined. One is the characteristic impedance $Z_0$ the other is the field impedance $Z_w$ (ratio of E to H field magnitude).

\[ Z_0 = Z_w \]

The coax is terminated with its characteristic impedance. You can change the inner diameter, the outer diameter and the material between the inner and the outer diameter (magnetic material is OK).

\[ Z_0 = \frac{138}{\sqrt{k}} \log \frac{d_1}{d_2} \]

Where,
- $Z_0$ = Characteristic impedance of line
- $d_1$ = Inside diameter of outer conductor
- $d_2$ = Outside diameter of inner conductor
- $k$ = Relative permittivity of insulation between conductors

Log in the equation is the natural logarithm

b) Can your solution be realized from a material and mechanical point of view?
Problem A12  Area: Waves, Devices, and Optics  Code:_____

An incident uniform electromagnetic plane wave propagates through free space \((\epsilon = \epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}, \mu = \mu_0 = 4\pi \times 10^{-7} \text{ H/m}, \sigma = 0)\). The electric field phasor associated with this electromagnetic wave is

\[ \mathbf{E}(\mathbf{r}) = [\mathbf{x} + 3\mathbf{y} - 2] \exp[-j(x + y + 4z)] \]

The incident electromagnetic wave encounters a dielectric boundary. The boundary is described geometrically by a plane satisfying

\[ x + \frac{1}{2}y + z = 0 \]

a) Find the angular frequency \((\omega)\) of the incident plane wave.

b) Find the magnetic field (magnitude AND direction) of the parallel polarized part of the incident electromagnetic plane wave. Your answer should be written in a form similar to the expression given above for \(\mathbf{E}(\mathbf{r})\). Parallel polarization refers to an electromagnetic wave for which the electric field is parallel to the plane of incidence.
A moving average (MA) filter is commonly used in DSP systems. An MA filter is defined as

\[ y[n] = \frac{1}{2M + 1} \sum_{m=-M}^{M} x[n - m] \]

with \( M = 3 \).

1. Determine the properties of the filter in terms of its stability, causality, and linearity.
2. Find the impulse response, frequency response, and group delay of the filter;
3. Sketch the frequency response of the filter. Clearly mark all important points on both axes.
4. If you choose \( M = 40 \), how would the frequency response of the filter change?
A message signal is the input to a modulator with carrier \( c(t) = A_c \cos(2\pi f_c t) \), where \( A_c = 20 \) and \( f_c = 1000 \text{ Hz} \). The magnitude spectrum of the message signal \( m(t) \) is shown in Fig. 2. The modulated signal is \( x_c(t) \) and its double-sided spectrum is denoted as \( X_c(f) \).

Answer the following questions. (5pts each)

![Magnitude spectrum of the message signal](image)

**Figure 2: Magnitude spectrum of the message signal \( m(t) \)**

1. Sketch \( |X_c(f)| \) if the modulation is double sideband (DSB). Please label all axes.
2. Sketch \( |X_c(f)| \) if the modulation is AM with a modulation index \( \alpha = 0.5 \). Assume that \( \min[m(t)] = -G_m \). Please label all axes.
3. Sketch \( |X_c(f)| \) if the modulation is single sideband (SSB), upper sideband (USB).
4. Sketch the block diagrams of the USB modulator and demodulator.
Let two random variables $X$ and $Y$ have joint pdf

$$f_{X,Y}(x, y) = \begin{cases} \frac{1}{4} & 0 \leq x \leq 2 \text{ and } 0 \leq y \leq 2 \\ 0 & \text{others} \end{cases}$$

1. Find the joint cdf of $X$ and $Y$.
2. Find the mean of $X$ and $Y$, respectively.
3. Find the variance of $X$ and $Y$, respectively.