Write a set of node-voltage equations in matrix form for the circuit below, using the space provided. Evaluate $v_1$, $v_2$, $v_3$, and $v_4$.

\[
\begin{bmatrix}
  v_1 \\
  v_2 \\
  v_3 \\
  v_4 
\end{bmatrix} =
\begin{bmatrix}
  \cdot \\
  \cdot \\
  \cdot \\
  \cdot 
\end{bmatrix}
\]
Find the steady-state voltage, $v_x(t)$, in the following circuit.
Two large conducting plates are placed a distance “$d$” apart and are located in freospace. The lower plate is held at zero potential ($\Phi = 0$), and the upper plate is held at a potential of $V_0$ ($\Phi = V_0$). Note: edge effects can be neglected.

- Find the potential, $\Phi$, in the region between the plates.
- Find the electric field intensity, $E$, in the region between the plates.
- Find the electric flux density, $D$, in the region between the plates.
- What is the surface charge density, $\rho_s$, on the upper and lower plates? Recall that the magnitude of the normal component of the electric flux density is equal to $\rho_s$. 
Problem: A lossless transmission line is shown below with internal source resistance, \( R_s = 3Z_0 \), and load resistance, \( R_L = 9Z_0 \). Here \( Z_0 \) is the characteristic impedance of the transmission line.

(That is \( Z_0 = \sqrt{\frac{L}{C}} \) and \( L \) and \( C \) are the inductance and capacitance per unit length of the transmission line.)

(a) Sketch the bounce diagrams for the voltage and current. What are the values of the initial voltage, \( V_1^+ \), and the initial current, \( I_1^+ \)?

(b) Plot the voltage at the load location, \( V_L(t) \), as function of time, \( t \), up to 6 times of the transit time.

(c) Plot the current at the load location, \( I_L(t) \), as function of time, \( t \), up to 6 times the transit time.
Consider a silicon (Si: a Col. IV material) abrupt-junction pn diode in which only donors are on the n-side and only acceptors are on the p-side. \( T = 300 \text{ K} \). Important physical constants are:

- Boltzmann's constant: \( k = 1.38 \times 10^{-23} \text{ J/K} = 8.62 \times 10^{-5} \text{ eV/K} \)
- Planck's constant: \( h = 4.14 \times 10^{-15} \text{ eV-s} \)
- Carrier Mobilities: \( \mu_n = 1350 \text{ cm}^2/\text{V-s} \) \( \mu_p = 480 \text{ cm}^2/\text{V-s} \)
- Bandgap Energy of Si: \( E_g = 1.11 \text{ eV} \)
- Intrinsic Carrier Concentration: \( n_i = 1.50 \times 10^{10} \text{ cm}^{-3} \) at 300 K

(a) Name the bias condition for which the following current types are dominant.

<table>
<thead>
<tr>
<th>Dominant Current</th>
<th>Bias Condition (Reverse Bias or Forward Bias)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffusion Current:</td>
<td></td>
</tr>
<tr>
<td>Drift Current:</td>
<td></td>
</tr>
</tbody>
</table>

(b) If an applied voltage is present, state how the depletion region width changes relative to the equilibrium depletion width. Circle the correct choices

- Forward bias: Increases
- Reverse bias: Increases

(c) The contact potential is \( V_s = 0.70 \text{ V} \). Calculate the doping concentrations for the p and n sides if the doping concentrations on each side are equal.

(d) For the diode circuit below, the turn-on voltage is \( V_w = 0.70 \text{ V} \), the reverse saturation current is 0.50 mA, and the breakdown voltage is -15 V. If \( R = 2,000 \Omega \) and \( V_s = +10 \sin(10t) \text{ V} \), calculate the operating point \((V, I)\) for \( V_s = +10 \text{ V} \) and \( V_s = -10 \text{ V} \).

[Diagram of diode circuit with labels]
A uniform plane wave propagating in air given by 

\[ \vec{E}_i(x, z) = \pi \epsilon_0 e^{j2\omega x - j\beta_0 z} (120\hat{x} - 50\hat{z}) \text{ (V/m)} \]

is incident on a perfect electric boundary (PEC) wall located at \( x = 0 \). Find the magnetic field of the reflected wave.
Consider the following block diagram.

Determine the transfer function. Show your work clearly.
Given the system below, for which three lead compensators have been designed.

![System Diagram]

\[ G(z) = \frac{0.0242(z + 0.967)}{(z - 1.0)(z - 0.9048)} \]

The desired closed-loop poles are \(0.677 \pm j0.246\) which correspond to 10% overshoot and a 2% settling time of 12T. The following three \(D(z)\) lead compensators have been designed using root locus techniques. Rank the designs from best to worst and state your reasons for your choice. Consider such factors as good design practice, meeting design specifications when actually implemented, etc. Additional calculations are not required.

\[ D_1 = 3.39 \frac{(z - 0.910)}{(z - 0.443)} \]

\[ D_2 = 6.42 \frac{(z - 0.677)^2}{(z - 0.443)^2} \]

\[ D_3 = 23.17 \frac{(z - 0.554)^2}{z^2} \]
Consider the following system

\[
\begin{align*}
R(s) & + E_{in}(s) \\
\frac{100}{s(s + 10)} & \\
\frac{1}{s + 5} & \rightarrow C(s)
\end{align*}
\]

Calculate the steady-state error for the ramp input.
A superheterodyne receiver uses an IF frequency of 455 kHz. The receiver is tuned to a transmitter having a carrier frequency of 1650 kHz.

1. Determine the frequencies of the local oscillator corresponding to low-side and high-side tuning.

2. Sketch the block diagrams of the AM transmitter and receiver, specifying all parameters if a filter is used.
In 1962, AT&T first offered digital telephone transmission referred to as T1 service. With this service, each T1 frame is partitioned into 24 time-division multiplexed channels or time slots. Each time slot contains 8 bits (one speech sample), and there is one additional bit per frame for alignment. The speech signal of each channel is sampled at 8000 samples per second. The bandwidth used for transmitting the composite T1 signal is 386 kHz. Find the bandwidth efficiency (bits/s/Hz) for this signalling scheme.