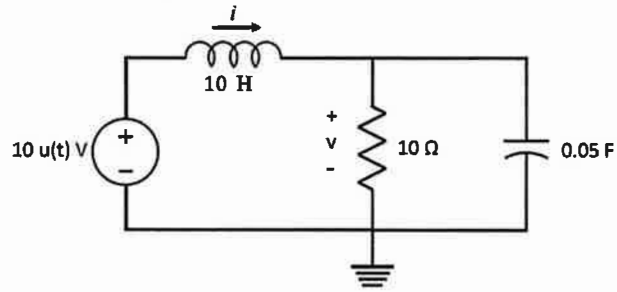
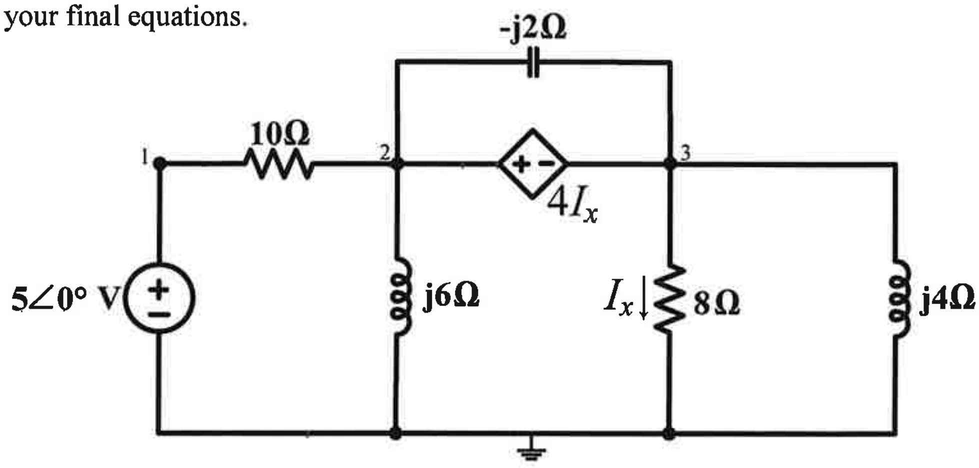
**Problem : Q1,** **Area: Circuits/Electronics** **Student Code:** ____

For the following circuit, find the complete response (particular + natural) $v(t)$ for $t > 0$. Consider the current of the inductor and the voltage of the capacitor to be zero at time zero.



**Problem : Q2** **Area: Circuits/Electronics** **Student Code:** ____

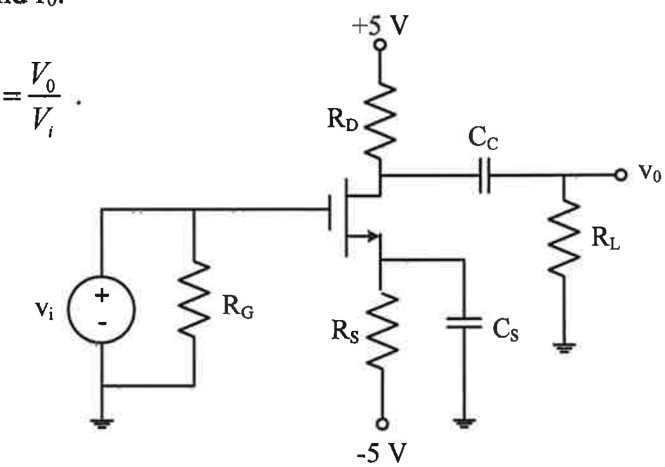
Use node voltage analysis to write node voltage equations for $\vec{V}_1$, $\vec{V}_2$, and $\vec{V}_3$ in a matrix form. You must not have the control variable in your final equations.



**Problem : Q3** **Area: Circuits/Electronics** **Student Code:** ____

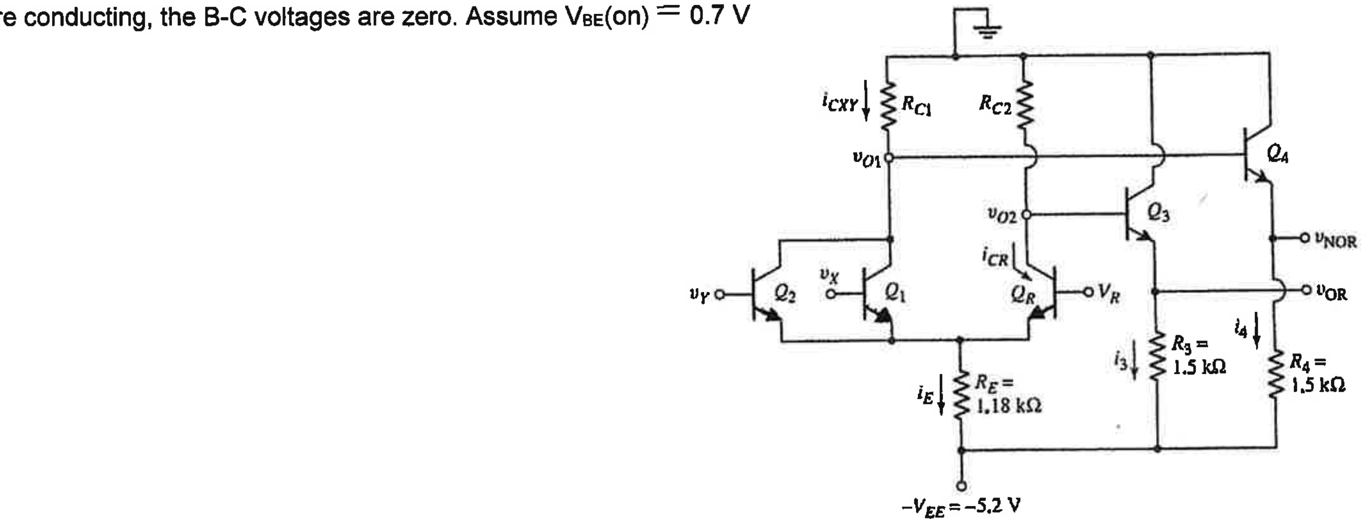
The MOSFET in the circuit below has a threshold voltage of 0.8 V, $K_n$=0.85 mA/V$^2$, and $\lambda$=0.02 V$^{-1}$. The transistor is in saturation with $I_{DQ}$=0.1 mA. If $R_S$=38.6 kΩ, $R_D$=6.43 kΩ, and $R_L$=40 kΩ,

a. Calculate the small signal parameters, $g_m$ and $r_0$.
b. Sketch the small-signal equivalent circuit.
c. Calculate the small-signal voltage gain, $A_v = \frac{V_0}{V_i}$.



**Problem : Q4** **Area: Circuits/Electronics** **Student Code: ____**

Consider the following Emitter Controlled Logic (ECL) circuit. Determine $R_{c1}$ and $R_{c2}$ such that when $Q_1$, $Q_2$, and then $Q_R$ are conducting, the B-C voltages are zero. Assume $V_{BE}(on) = 0.7$ V



**Problem : 9** **Area: Controls** **Student Code:** ____



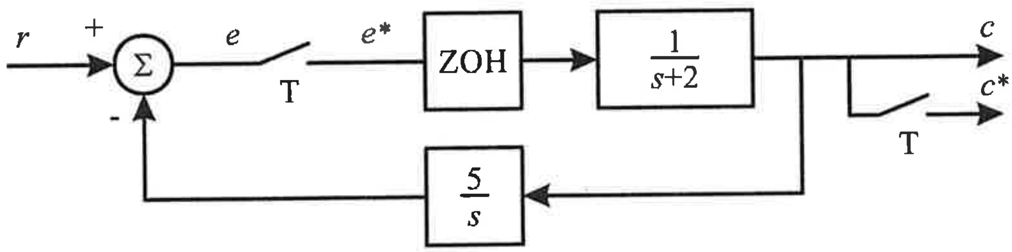
Use the Routh-Hurwitz test to find the number of roots, if any, of the following characteristic equation that are in the right half-plane. Also determine the number of left half-plane and imaginary axis roots.

$$s^5 + 3s^4 - 2s^3 + 4s^2 - 24s - 32 = 0$$

**Problem : 11** **Area: Controls** **Student Code:** ____



For the following control system, determine the z-transform description of the sampled output in terms of the sampled input.



**Problem: 13** **Area: Power** **Student Code:______**

A 2-pole, 50 Hz, 690 V, 250 kVA three-phase synchronous generator has a synchronous reactance of 0.70 Ω. It is connected to a 690 V, 50 Hz three-phase bus. Take phase A of the terminal voltage, line-to-neutral, as your angle reference if need be.

a. For an output power of $150\measuredangle 0°$ kVA (total three-phase), determine the generated voltage $\hat{E}_a = E_a \measuredangle \delta$. Also determine the line current magnitude

b. For active output power of 150 kW, determine the minimum generated voltage (magnitude), the corresponding reactive power, and the line current magnitude.

Helpful equations:

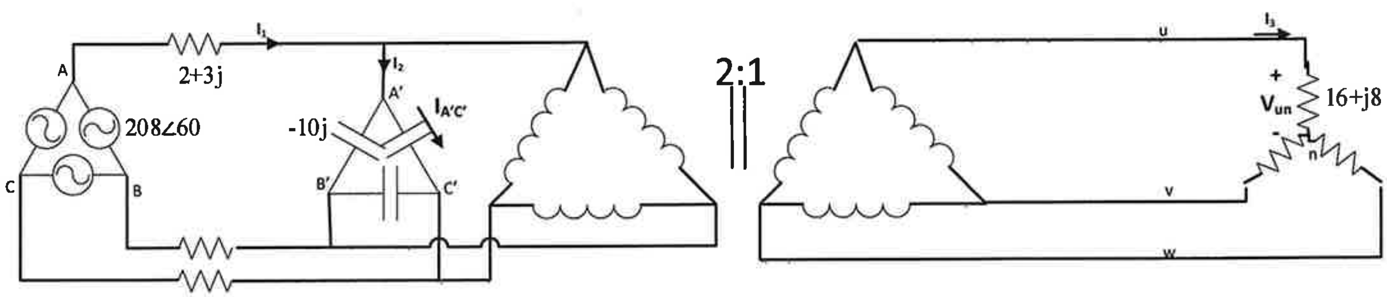
$$P_a = \frac{V_a E_a}{X_s} \sin\delta$$

$$Q_a = \frac{V_a E_a}{X_s} \cos\delta - \frac{V_a^2}{X_s}$$

**Problem 14:** **Area: Power** **Student Code:** ______

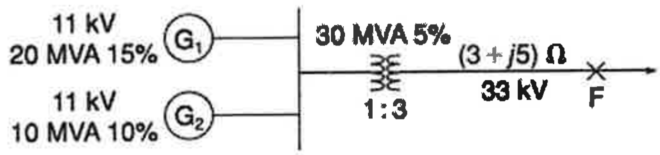
In the following circuit, find the following (both amplitude and angle):

a) $I_1$, $I_2$, and $I_3$.
b) $I_{A'C'}$ (Capacitor current).
c) Phase voltage of the load (16+8j) equal to $V_{un}$.
d) 3-phase complex power of the source.
e) 3-phase complex power of the capacitor bank.



**Problem: 16** **Area: Power** **Student Code:______**

In the system shown below, a three-phase short circuit occurs at point F. Assume that prefault currents are zero and that the generators are operating at rated voltage. Choose base MVA as 30 MVA and the base line voltage at the HV-side of the transformer to be 33kV. Determine the fault current.

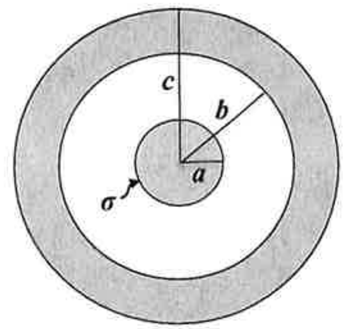


**Problem : 17** **Area: Waves & Devices** **Student Code:____**

**Concentric spherical metal shell.** The figure below shows a cross-section of a concentric spherical metal shell. The radii of the inner solid spherical conductor, the inner wall of the outer spherical conductor, and the outer wall of the outer spherical conductor are $\boldsymbol{a}$, $\boldsymbol{b}$, and $c$, respectively, as marked in the figure. Consider a positive surface charge density $\boldsymbol{\sigma}$ at the surface of the inner spherical conductor.

A) Find the electric field everywhere as a function of radial distance $\boldsymbol{r}$ (i.e., $r < a$, $a < r < b$, $b < r < c$ and $r > c$).

B) Please plot the electric field strength as a function of radial distance $\boldsymbol{r}$.



Consider an antenna that has a directivity $D = 3$ dBi at 1 GHz in a certain direction. Total antenna efficiency $\varepsilon_a = 50$ %. Determine the voltage a plane wave with the amplitude of 1 V/m, illuminating the antenna from the direction the directivity is given for, will induce at the 50 Ohm resistor attached to the antenna port (assume that the polarization of the plane wave matches the polarization of the antenna, i.e. the polarization mismatch is irrelevant).

Useful formulas:

Power received by the antenna

$$P_{received} = S_{inc} A_e$$

where $S_{inc}$ is the incident power density,

$$A_e = \frac{\lambda^2}{4\pi} G$$

is the effective aperture of the antenna,

$$G = \varepsilon_a D$$

is the antenna gain.

**Problem : 20** **Area: Waves & Devices** **Student Code:____**

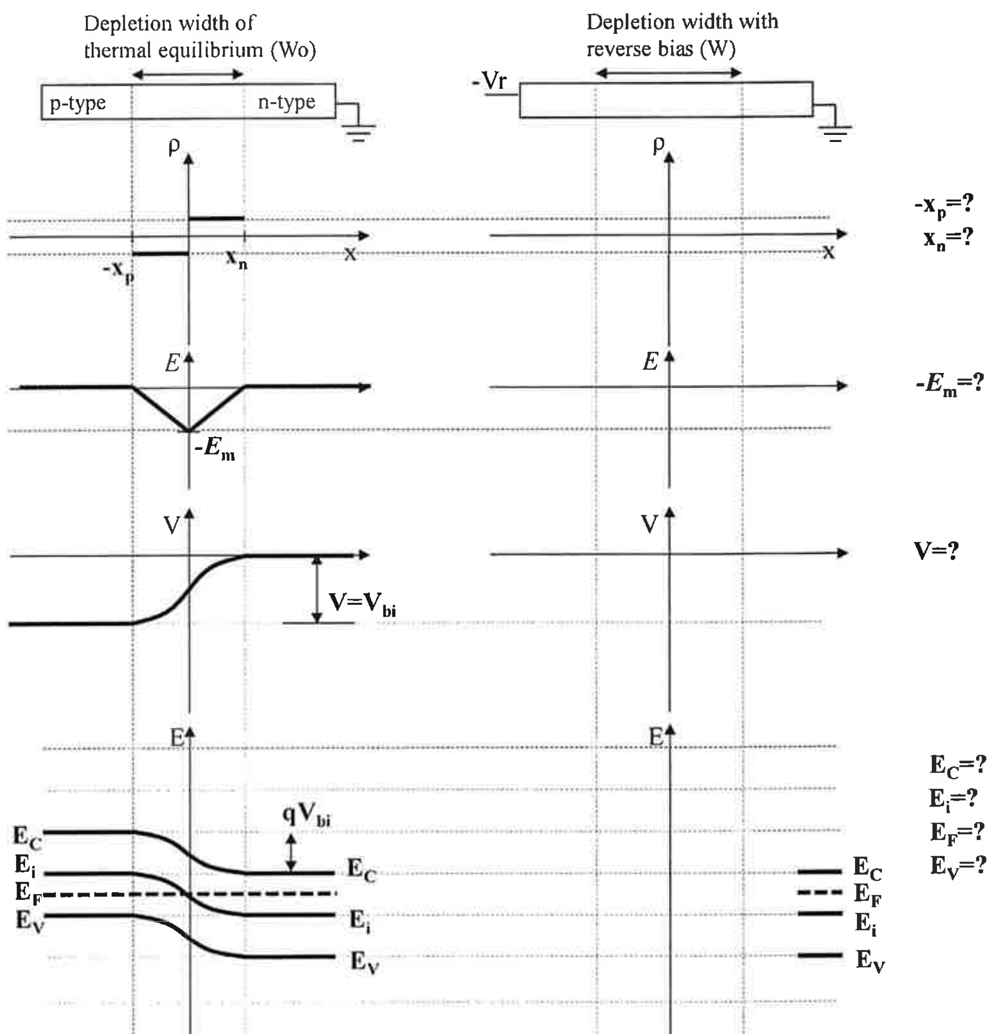
1. [30%] An abrupt silicon p-n junction diode has a net acceptor concentration $10^{17}$cm$^{-3}$ in the p-side and a net donor concentration $10^{17}$cm$^{-3}$ in the n-side, respectively. Calculate the potential difference across the depletion region (or space charge region) at thermal equilibrium (i.e. contact potential or built-in potential) in room temperature (300K).

2. [35%] Complete the diagrams and mark all question-marked items of the reverse-biased symmetric p-n junction (i.e. Show the expected difference when a reverse bias is applied). Assume the n-side is electrically grounded. The dashed lines serve only as "reference lines" to indicate the values of each item in its equilibrium condition.

3. Consider a silicon sample doped with donors ($10^{14}$ cm$^{-3}$) at room temperature. Excess carriers by photon absorption (steady-state concentrations of 2.0 x $10^{13}$ cm$^{-3}$) are generated during a light illumination. Answer the following questions assuming electron mobility = 1,500 cm$^2$/V·sec and hole mobility = 500 cm$^2$/V·sec, respectively.

a. [25%] What is the ratio between the conductivity ($\sigma$) with illumination and the conductivity ($\sigma$) without illumination, i.e. $\sigma_{(with\ illum)}$ / $\sigma_{(without\ illum)}$.

b. [10%] Discuss a possible application of this sample (must be no more than one sentence or ~20 words).




| Constants* | Equations* |
| --- | --- |
| ▪ Elementary charge = 1.6 x $10^{-19}$ [C]<br>▪ kT = 0.0259 [eV] (at 300 K)<br>▪ Intrinsic concentration = 9.65 x $10^9$ [cm$^{-3}$] (for silicon at 300 K) | ▪ $n_o p_o = n_i^2$<br>▪ $n_o = n_i \exp[(E_F - E_i) / kT]$ or $(E_F - E_i) = kT \ln(n_o/n_i)$<br>▪ $p_o = n_i \exp[(E_i - E_F) / kT]$ or $(E_i - E_F) = kT \ln(p_o/n_i)$<br>▪ $\sigma = q(n\mu_n + p\mu_p)$ |

* Definitions of parameters are not given for the provided information. It is expected that the examinees interpret the meaning.

Given the truth table shown, implement the function F(A,B,C,D) using:

a) a 4:1 Mux plus any other additional basic logic gates

b) an 8:1 Mux plus any other additional basic logic gates

| A B C D | F |
|---|---|
| 0 0 0 0 | 1 |
| 0 0 0 1 | 0 |
| 0 0 1 0 | 0 |
| 0 0 1 1 | 1 |
| 0 1 0 0 | 0 |
| 0 1 0 1 | 0 |
| 0 1 1 0 | 1 |
| 0 1 1 1 | 1 |
| 1 0 0 0 | 0 |
| 1 0 0 1 | 1 |
| 1 0 1 0 | 1 |
| 1 0 1 1 | 1 |
| 1 1 0 0 | 0 |
| 1 1 0 1 | 0 |
| 1 1 1 0 | 0 |
| 1 1 1 1 | 1 |

c) two 3x8 Active-Low Decoders with ACTIVE-LOW Enable, an 8-input AND, and an inverter.

**Problem: P30** **Area: Integrated Circuits and Logic Design** **Student Code:____**

Answer the following questions.

a) Implement Z = 3X - 4Y in 8-bit 2's complement using only 16 Full Adders and 8 inverters; assume $X = 00x_5x_4x_3x_2x_1x_0$ and $Y = 00y_5y_4y_3y_2y_1y_0$.

b) Assume that the delay per sum operation is 3ns, the delay per carry operation is 2ns, and the delay per inverter is 1ns; how long does it take to calculate $z_7$?