1) (10 points) PN Junction Electrostatics

For a \textit{pn} junction diode, the acceptor concentration is \( N_A = 2 \times 10^{16} \) \( \text{cm}^{-3} \) and the donor concentration is \( N_D = 2 \times 10^{15} \) \( \text{cm}^{-3} \).

Assume \( n_i = 1.68 \times 10^{10} \) \( \text{cm}^{-3} \) and the junction area is \( A = 400 \mu\text{m}^2 \).

(a) (2 points) Find the junction built-in voltage \( V_b \).

(b) (4 points) Find the width of the depletion region, \( W_{dep} \) when the junction is reverse biased with \( V_B = 5 \) \( \text{V} \).

(c) (4 points) Calculate the total junction capacitance \( C_J \) when the junction is reverse biased with \( V_B = 5 \) \( \text{V} \).

2) (10 points) Square-Root Amplifier

The circuit with an ideal OP amp shown below can be considered a square-root amplifier. Determine \( V_{\text{out}} \) in terms of \( V_{\text{in}} \) and compute the small-signal gain by differentiating the result with respect to \( V_{\text{in}} \).

3) (10 points) MOSFET DC Analysis

For the circuit shown below, \( \mu_e C_o = 50 \mu\text{A}/\text{V}^2 \), \( \mu_f C_o = 20 \mu\text{A}/\text{V}^2 \), \( \frac{W}{L} = \frac{30 \mu\text{m}}{10 \mu\text{m}} \), \( V_{\text{gs}} = -V_{\text{ds}} = 1 \) \( \text{V} \), \( \lambda = 0 \), \( \gamma = 0 \), find the labeled currents and voltages (\( I_D \) and \( V_D \)).

4) (10 points) MOSFET Amplifier

Consider the circuit shown below. \( V_B \) is a fixed DC voltage. Find \( R_D \) and \( W/L \) so that the voltage gain \( A_v = 4 \) \( \text{V/V} \) and the input resistance \( R_{in} = 50 \) \( \Omega \). Assume \( I_D = 0.5 \) mA, \( \lambda = 0 \), threshold voltage \( V_T = 0.4 \) \( \text{V} \) and \( \mu_e C_o = 200 \mu\text{A}/\text{V}^2 \) for NMOS device. Ignore the body effect too.
5) (5 points) Current Steering Circuit

Calculate the $I_{\text{copy}}$ of the following circuit. Assume all transistors operate in saturation.

6) (10 points) Please design a CMOS current mirror with $I_{\text{ref}} = 0.2\, \text{mA}$. Assume $k_n = |k_p| = 1\, \text{mA}/\sqrt{V}$, $V_{\text{DD}} - V_{\text{SS}} = 1\, \text{V}$, and $\gamma = 0$ (可用元件為N沟道MOS、PMOS、R、L、V)

7) (5 points) Draw and explain the four basic feedback topologies.

8) (10 points) Please find the CMRR of the circuit shown in figure below. Assume that for all transistors, $W/L = 7.2\, \mu\text{m}/0.36\, \mu\text{m}$, let $\mu_n C_{\text{ox}} = 387\, \mu\text{A}/\sqrt{V}$, $\mu_p C_{\text{ox}} = 86\, \mu\text{A}/\sqrt{V}$, $V_{\text{th}} = 5\, \text{V}/\mu\text{m}$, $V_{\text{thp}} = 6\, \text{V}/\mu\text{m}$. The bias current $I_{\text{b}} = 0.2\, \text{mA}$, and the bias current source has an output resistance $R_{\text{ss}} = 25\, \text{k} \Omega$.

9) (20 points) 見圖-1-A 和其其其文字說明。假設 LED 亮度與電流成正比。回答以下問題:

(a) 圖-1-B 之電路中，(A)只有紅光發亮 (B)只有綠光發亮 (C)只有藍光發亮 (D)一樣亮

(b) 圖-1-C 之電路中，(A)紅光最亮 (B)綠光最亮 (C)藍光最亮 (D)一樣亮

(c) 圖-1-D 之電路中，(A)紅光最亮 (B)綠光最亮 (C)藍光最亮 (D)一樣亮

(d) 哪一電路所消耗功率(Power)最大 (A) 圖-1-B (B) 圖-1-C (C) 圖-1-D (D) 一樣大

(以上單選題每題5分，答錯倒扣2分)
左圖為一般 LED 之電壓電流特性
曲線 V1, V2, V3, 分別代表紅光, 綠光, 藍光 LED 在電流約為 1 mA 時
的導通電壓。假設其中:
V1 = 1.8 Volt (RED)
V2 = 2.2 Volt (GREEN)
V3 = 3.0 Volt (BLUE)

10) (10 points) 利用一般運算放大器（如 μA 741）設計一 LED 亮度控制電路滿足圖-2之規格: