1. Consider a 4-bit digital word $D = b_3\, b_2\, b_1\, b_0$ used to represent an analog signal v_A that varies between 0 V and + 15 V. Give D corresponding to v_A = 9 V and 11 V. (8 %)

2. Explain the following terminologies: (12 %)
   (a) Ideal operational amplifier
   (b) Noise margin
   (c) Early voltage

3. Assume the operational amplifier for following figure is ideal. What is the output voltage v_o if the resistance of R_x is 60 kΩ? (8 %)
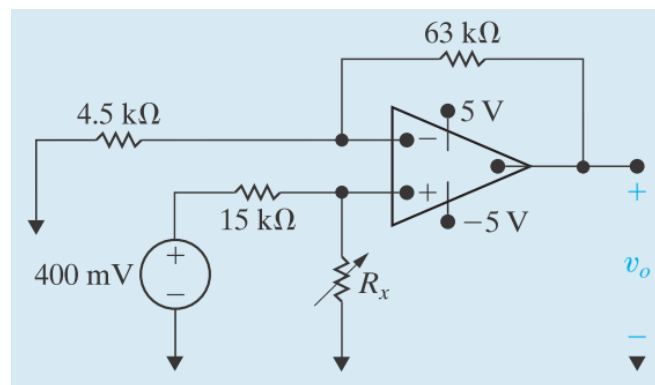
4. For a pn junction with $N_A = 10^{17}/cm^3$ and $N_D = 10^{16}/cm^3$, find, at T = 300 K, (a) the built-in voltage, V_0, (b) the width of the depletion region, W_{dep}, and (c) the distance it extends in the p side, x_p, and the n side of the junction, x_n. Use n_i = 1.5 x $10^{10}/cm^3$, V_T = 25 mV, and ε_s = 1.04 x 10^{-12} F/cm at T = 300 K. (12 %)

5. For the circuit shown in Fig.1, the transistor has β = 100 and $V_A = \infty$. (1) Find the dc current I and the dc voltage V_{CB} if v_s = 0. (2) Determine the small-signal voltage gain v_o/v_s, and the output resistance R_o. (20%)

6. In the circuit of Fig. 2, the transistor has W/L = 100, χ = 0.2, and λ = 0.05 V^{-1}, V_{OV} = 0.5 V, and $k'_n = 160\mu A/V^2$. (1)What is the amplifier configuration? (CS, CG, CD). (2)Determine the bias current I and voltage gain v_o/v_i. (10%)

7. An NMOS differential pair is biased by a current source I = 0.2 rnA having an output resistance R_{CS} = 200 kΩ. The amplifier has drain resistances R_D = 20 kΩ, using transistors with k'_n = 200 μA/V, W/L = 10, and neglecting r_o. If the output is taken differentially and there is a 2% mismatch between the drain resistances, find $|A_d|$, $|A_{cm}|$, and CMRR. (15%)

8. A common-source amplifier has R_{in} = 200 kΩ, R_D = 10 kΩ. The transistor has g_m = 2 mA/V, r_o = 100 kΩ, C_{gs} = 1.5 pF, and C_{gd} = 0.5 pF. The amplifier is fed from a voltage source v_s with an internal resistance of 200 kΩ and is connected to a 10 kΩ load. Find: (a) the overall midband voltage gain $A_M = v_o / v_s$. (b) the upper 3-dB frequency f_H. (15%)
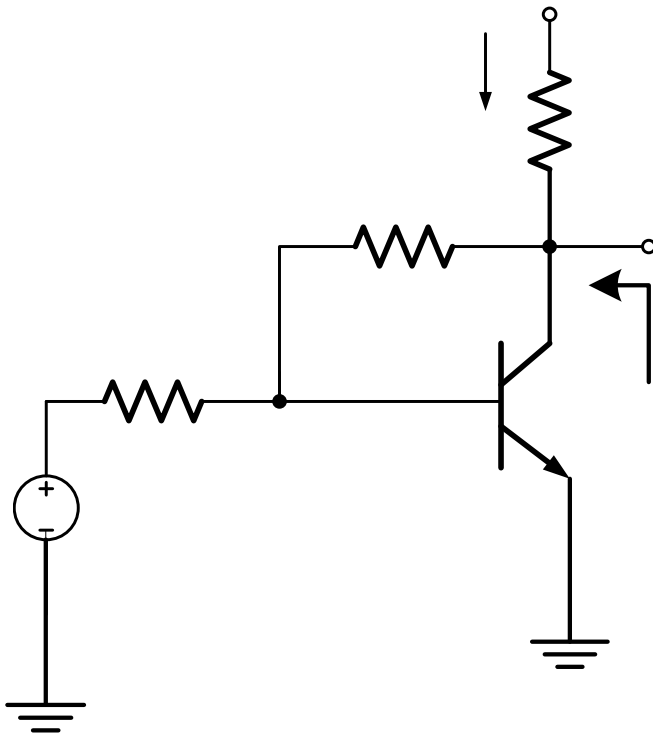

Fig. 1

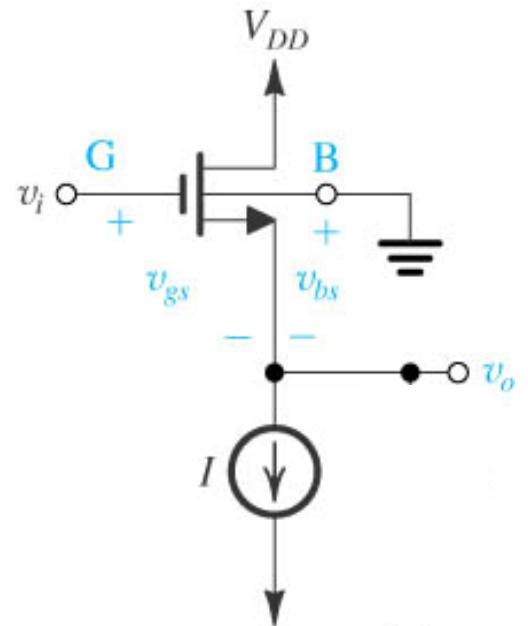**Fig. 2**

12 V