Problem #1
Bipolar Amplifier

Given: npn: $n = 100$, Early voltage $V_{AN} = 100V$

pnp: $p = 20$, Early voltage $V_{AP} = 50V$

The voltage $V_{IN}$ is adjusted so that the DC output voltage level $V_{OUT} = 0V$.

The resistances $r_{oc}$ of the current sources are infinite. The various small-signal resistances referred to in parts (b)-(d) are defined on the schematic.

If you do not have time to find numerical values, leave the answer in symbolic form—be sure to include subscripts to identify which transistor the parameter is for.

(a) (3 pts) Find the DC values of $V_{CE1}$, $V_{EC2}$, and $V_{CE3}$. You can neglect base currents.

(b) (3 pts) Find the numerical value of the input resistance $R_i$.

(c) (4 pts) Find the numerical value of the output resistance of the first stage, $R_{o1}$.

(d) (4 pts) Find the numerical value of the output resistance $R_o$. Given: the output resistance of the second stage is $R_{o2} = 500K\Omega$.

(e) (4 pts) Find the numerical value of the small-signal voltage gain $A_1$ between the voltage source $v_s$ and the collector of Q1: $A_1 = v_{c1}/v_s$
Problem #2
(18 points) fancy MOS current source

Given for all transistors: \( (W/L)=32 \), mobility\( \cdot \)\( Cox=100 \text{microA/V}^2 \), \( VTn=1 \text{V} \), \( \lambda n =0.01 \).

(a) (5 pts) Find the numerical value of \( R(\text{REF}) \) such that the output current is \( I_{\text{OUT}}=100 \text{microA} \)

(b) (3 pts) Find the numerical value of the drain voltage of transistor M2, \( V_{D3} \). If you could not solve part(a), assume that \( R(\text{REF})=25\text{KOhm} \), which is (of course) not the correct answer to part(a).

(c) (5 pts) What is the minimum value of the output voltage \( V_{\text{OUT}} \) for which all transistors are saturated?

(d) (5 pts) Find the numerical value of the output resistance \( r_{oc} \) of the current source. Given: \( g_m \cdot r_o=800 \) for all transistors.

Problem #3

Given: base-emitter junction is forward biased, base-collector junction is reverse biased, the base transport factor \( \alpha(T)=1 \) (meaning that no recombination occurs in the base).

Given: \( D_n=20 \text{cm}^2/\text{s} \), \( D_p=10 \text{cm}^2/\text{s} \). The area of the base-emitter junction is: \( A_E=10^{-5} \text{cm}^2 \).

(a) (3 pts) What is the numerical value of the electron diffusion current density in the base (units: \( \text{A/cm}^2 \))

(b) (3 pts) What is the numerical value of the hole diffusion current density in the emitter (units: \( \text{A/cm}^2 \))

(c) (4 pts) What is the numerical value of the collector current \( I_C \)?

(d) (4 pts) What is the numerical value of the current gain?