Q1.

$$I_o = \mu C_{ox} \frac{W}{2L} (V_{GS} - V_{TH})^2$$

$$= 100 \times 10^{-6} \times \frac{10}{2} \cdot (V_{GS} - 0.5)^2 = 100 \times 10^{-6}$$

So $5 (V_{GS} - .5)^2 = 1$; $(V_{GS} - .5)^2 = 0.2$

$$V_{GS} - 0.5 = \sqrt{.2} = \pm 0.447$$

$$V_{GS} = 0.947$$ (acceptable, ∵ > V_{TH})

$$V_{GS} = V_G - V_S = V_G + 5 = 0.947$$

So $V_G = -4.05$ V.

Since $I_{ref} = I_o$, MOS being identical

$$= 100 \mu A = \frac{V_{DD} - V_G}{R} = \frac{5 + 4.05}{R}$$

$$R = \frac{9.05}{100 \mu A} = 90.5 K\Omega$$ ← design value (Ans)

Q2.

$$I_o = I_{REF} \frac{1}{1 + \frac{n+1}{\beta}}$$

'n' not given, let $n = 1$

$$I_{REF} - I_o = I_{REF} \left[1 - \left(\frac{1}{1 + \frac{n+1}{\beta}} \right) \right]$$

$$= I_{REF} \left[\frac{1 + \frac{n+1}{\beta} - 1}{1 + \frac{n+1}{\beta}} \right] = I_{REF} \cdot \frac{n+1}{\beta + n + 1}$$

$$\frac{I_{REF} - I_o}{I_{REF}} = \frac{n+1}{\beta + n + 1}$$ This should be < 5%

Q2

So $\dfrac{n+1}{\beta+n+1} < .05$, $\beta > \dfrac{(n+1)(1-.05)}{.05}$

$\boxed{\beta > 19(n+1)}$

p2/4

If $n=1$, $\dfrac{2}{\beta+2} < .05$

$.05\beta + 0.1 > 2$; $.05\beta > 1.9$

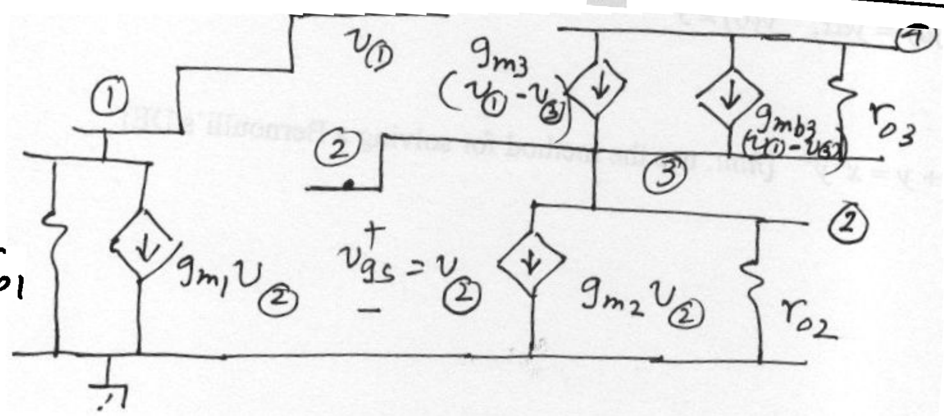
$\beta > \dfrac{1.9}{.05} = 38$

If $n=2$; $\dfrac{3}{\beta+3} < .05$

$.05\beta + .15 > 3$; $.05\beta > 2.85$

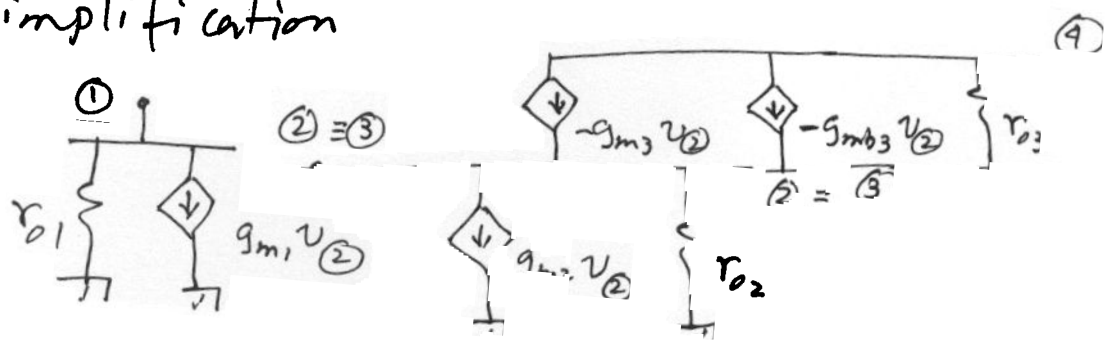
$\beta > 57$.

Q3:



note:
$v_{③} \equiv v_{②}$

∵ I_{REF} is DC no 'ac' current at node ①
So we can take $v_{①} = 0$. for further simplification



Q4:

We need to use degenerating resistors in series with each emitter arm.

With R_E as this resistance,

$$R_{in} = 2(\beta+1)(R_E + r_e)$$

The voltage drop $2v_{be}$ is across $2(\beta+1)r_e$ component

So $2(\beta+1)\, r_e < 6\ mV$ (rms)

or $(\beta+1)\, r_e < 3\ mV$.

For given problem, the total drop across $2(\beta+1)(R_E+r_e)$ is 50 mV

i.e. $(\beta+1)(R_E + r_e) = 25\ mV$.

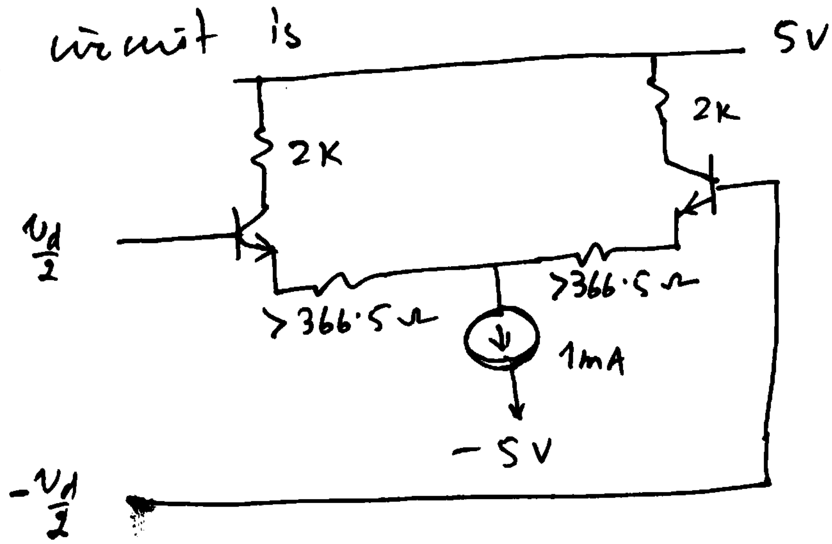
Taking the ratio: $\frac{R_E + r_e}{r_e} > \frac{25\ mV}{3\ mV} \rightarrow 8.33$

$R_E > (8.33 - 1)\, r_e \rightarrow 7.33\, r_e$

$r_e \simeq \frac{V_T}{I_E} = \frac{25\ mV}{0.5\ mA} = 50\ \Omega$

So $R_E > 7.33 \times 50 \rightarrow 366.5\ \Omega \rightarrow 390\ \Omega$ a practical value

Modified circuit is



Q.5: With active load, the differential gain is $-g_m \cdot (r_{o1} \| r_{o2})$

Where $r_{o1} = \frac{V_{AN}}{I_{CN}}$; $r_{o2} = \frac{V_{AP}}{I_{CP}}$

For the circuit $I_{CN} = I_{CP} \approx \frac{I_{EE}}{2} = 1\,mA$

So $r_{o1} = \frac{25}{1mA} = 25\,K\Omega$ $r_{o2} = \frac{50}{1mA} = 50\,K\Omega$

$g_m \approx \frac{I_E}{V_T} = \frac{1\,mA}{25\,mV} = 0.04$ mho.

Note: $I_E \cong I_{CN} \cong I_{CP}$

So voltage gain $= -.04 \times 50K\Omega \| 25K\Omega$

$= -.04 \times 16.67\,K\Omega = -666.67$ V/V.

Gain ≈ -666.67 V/V