

Q.1:

$$Q_2 \text{ has } I_{S2} = 4 \times I_{S1}$$

$$\therefore I_E, I_C \propto I_S$$

$$I_{C2} = I_0 \text{ is } 4 \times I_{C1}$$

$$\text{So } I_{C1} = 2 \text{ mA} / 4 = 0.5 \text{ mA}$$

$$\text{Similarly, } I_{B2} = 4 I_{B1}$$

and so on...

$$\text{Now: } I_{REF} = I_{C1} + I_{B1} + I_{B2}$$

$$I_{REF} = \frac{I_0}{4} + \frac{I_0}{\beta \times 4} + \frac{I_0}{\beta}$$

$$\therefore I_0 = 2 \text{ mA}, \beta = 100$$

$$I_{REF} = I_0 \left(\frac{1}{4} + \frac{1}{400} + \frac{1}{100} \right) \\ = 0.525 \text{ mA.}$$

To determine R, we need to know V_B at the base of Q_2 (and Q_1 too).

$$\text{Assuming } I_{C2} \approx I_{E2} \\ = I_{S2} \exp(V_{BE}/V_T)$$

$$V_{BE} = V_B = V_T \ln\left(\frac{I_{C2}}{I_{S2}}\right)$$

$$= 0.025 \times 2.303 \times \log\left(\frac{2 \times 10^{-3}}{10^{-14}}\right)$$

$$= 0.0576 \times 11.301$$

$$= 0.65 \text{ V}$$

$$\text{Hence, } R = \frac{5 - 0.65}{I_{REF}}$$

$$= \frac{4.35}{0.525} \text{ k}\Omega = 8.28 \text{ k}\Omega$$

$$\text{Ans: } \underline{8.28 \text{ k}\Omega}$$

X

Q. 2: We need to find

$$\exp(-v_D/v_T)$$

i) $v_D = 30 \text{ mV}$

$$\exp\left(-\frac{30}{25}\right) = 0.3012$$

$$\exp\left(\frac{30}{25}\right) = \exp\left(\frac{v_D}{v_T}\right) = 3.32$$

Then,
$$\frac{e^{-v_D/v_T}}{1 + e^{-v_D/v_T}} = \frac{0.3012}{1.3012}$$

$$= 0.2315$$

and
$$\frac{e^{v_D/v_T}}{1 + e^{v_D/v_T}}$$

$$= \frac{3.32}{4.32} = 0.768$$

So
$$v_{O1} - v_{O2} = 2 \times 10^3 \times 2 \times 10^{-3}$$

$$\times (0.2315 - 0.768)$$

$$= -4 \times 0.5370$$

$$= -2.148 \text{ V}$$

Voltage gain for $v_D = 30 \text{ mV}$
is then $-\frac{2 \cdot 148}{0.3} = -71.6$
V/V

(ii) Now $v_D = 2 \text{ mV}$

$$\exp(-v_D/v_T) = \exp\left(-\frac{2}{25}\right)$$

$$= 0.923$$

$$\exp(v_D/v_T) = 1.083$$

$$\text{Then } \frac{e^{-v_D/v_T}}{1 + e^{-v_D/v_T}} - \frac{e^{v_D/v_T}}{1 + e^{v_D/v_T}}$$
$$= \frac{0.923}{1.923} - \frac{1.083}{2.083}$$

$$= -0.0399$$

$$v_{o1} - v_{o2} = 2 \times 10^3 \times 2 \times 10^{-3} \times$$
$$(-0.0399)$$

$$= -0.1598$$

$$\text{So, voltage gain} = -\frac{0.1598}{0.02}$$

$$= -79.89 \text{ v/v}$$

002

Theoretical small signal gain = $g_m R_c$

$$\text{Here, } g_m = \frac{1 \text{ mA}}{25 \text{ mV}} = 0.04$$

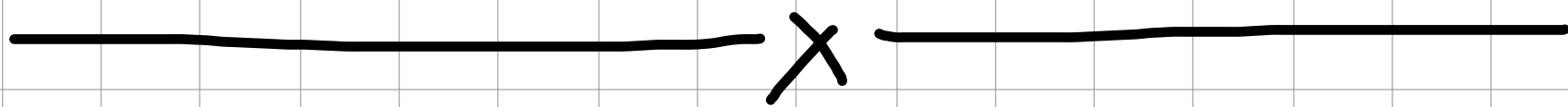
$$\text{So } | \text{gain} | = 2 \times 10^3 \times 0.04 \\ = 80$$

Comparison:

$$\text{i) } | \text{Gain} | = 71.6 < 80$$

$$\text{ii) } | \text{Gain} | = 79.89 \approx 80$$

The gain when v_d is \ll than 25 mV (i.e., V_T) is very close to the theoretical small signal gain value.



Q3.

The voltage gain is same as the gain of one-half of the circuit, i.e., $-g_m (r_{o1} \parallel r_{o3})$

I_c for each half $\approx 1 \text{ mA}$

In the given case

$$g_m = \frac{1 \text{ mA}}{25 \text{ mV}} = 0.04 \text{ V}^{-1}$$

$$r_{o1} = \frac{V_A (\text{NPN})}{1 \text{ mA}} = \frac{25 \text{ V}}{1 \text{ mA}} = 25 \text{ k}\Omega$$

$$r_{o3} = \frac{V_A (\text{PNP})}{1 \text{ mA}} = \frac{50}{1} = 50 \text{ k}\Omega$$

$$\begin{aligned} \text{So gain} &= -0.04 \times 25 \text{ k}\Omega \parallel 50 \text{ k}\Omega \\ &= -0.04 \times 16.67 \text{ k}\Omega \\ &= -666.8 \text{ V/V} \end{aligned}$$