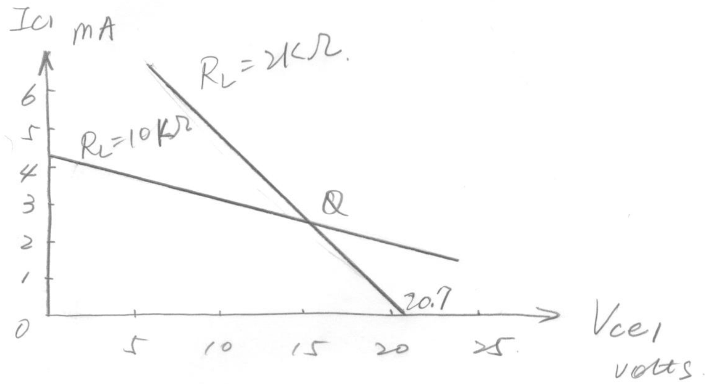
EE140 HW#6 Solution

1)

(a)



(b) $I_R = \dfrac{V_{CC} - V_{BE3}}{R_3} = \dfrac{15V - 0.7V}{5K\Omega} = 2.86\,mA$

$\therefore I_Q = 2.86\,mA$

For $R_L = 2K\Omega$

$\hat{V}_{OM} = 5.72V$, $\hat{I}_{OM} = 2.86\,mA$.

$\therefore P_{L,max} = \frac{1}{2} \times 5.72V \times 2.86\,mA = 8.2\,mW$

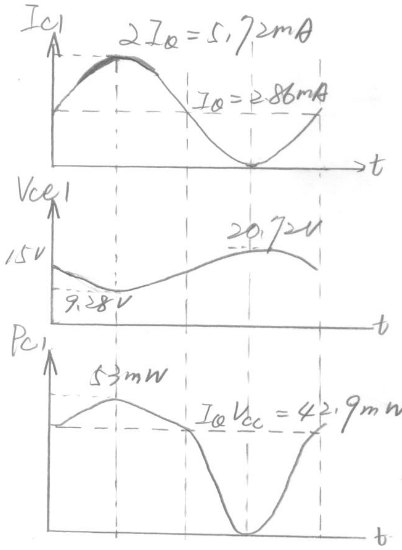
For $R_L = 10K\Omega$

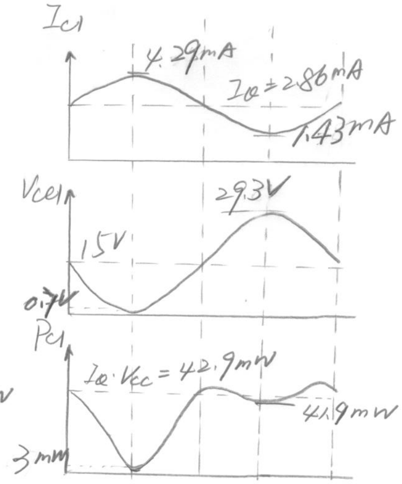
$\hat{V}_{OM} = V_{CC} - V_{BE} = 14.3V$; $\hat{I}_{OM} = \dfrac{\hat{V}_{OM}}{R_L} = 1.43\,mA$

$\therefore P_{L,max} = \frac{1}{2} \times 14.3V \times 1.43\,mA = 10.2\,mW$

$R_L = 2k\Omega$

$R_L = 10k\Omega$





(c). $R_L = 2k\Omega$

$$\eta_c = \frac{P_L}{P_{supply}} = \frac{8.2}{2 \times 42.9} = 9.6\%$$

$R_L = 10k\Omega$

$$\eta_c = \frac{10.2}{2 \times 42.9} = 11.89\%$$

(d) For maximum efficiency

$$R_L = \frac{V_{cc} - V_{BE}}{I_Q} = \frac{14.3}{2.86} k\Omega = 5k\Omega$$

$$P_L = \frac{1}{2} \frac{\hat{V}_{om}^2}{R_L} = \frac{1}{2} \frac{14.3^2}{5} mW = 20.5mW$$

2) The device model:

$K'_{NMOS} = 332\,\mu A/V^2$ $V_{TO,NMOS} = 0.3V$

$K'_{PMOS} = 133\,\mu A/V^2$ $V_{TO,PMOS} = -0.3V$

$V_{O+} = V_{DD} - V_{dsat4b} - V_{T1a} - V_{dsat1a}$

$V_{dsat4b} = \sqrt{\dfrac{2I_{4b}}{K_p' \cdot (\frac{W}{L})_{4b}}} = \sqrt{\dfrac{2 \times 10\mu A}{133\mu A/V^2 \times \frac{0.5}{0.08}}} = 155mV$

$V_{T1a} = V_{TO,NMOS} = 0.3V.$

$\therefore V_{dsat1a} = V_{DD} - V_{dsat4b} - V_{T1a} - V_{O+}$

$= 1.2V - 155mV - 0.3V - 0.6V$

$= 145mV$

$I_{1a} = \dfrac{V_{O+}}{1K\Omega} = \dfrac{0.6V}{1K\Omega} = 0.6mA.$

Since $V_{dsat1a} = \sqrt{\dfrac{2I_{1a}}{K_n' \cdot (\frac{W}{L})_{1a}}} \Rightarrow (\frac{W}{L})_{1a} = \underline{171.9}$

pick $\underline{L = L_{min} = 0.13\mu}$ (minimum area) $\underline{W_{1a} = 13.75\mu}$

$L_{eff} = 0.08\mu.$

$$V_{o-} = -V_{DD} + V_{dsat3} + |V_{T1b}| + |V_{dsat1b}|$$

$$\therefore |V_{dsat1b}| = V_{o-} + V_{DD} - V_{dsat3} - |V_{T1b}|$$

$$= -0.6V + 1.2V - V_{dsat3} - 0.3V$$

$$V_{dsat3} = \sqrt{\frac{2I_B}{K'_n(\frac{W}{L})_3}} = \sqrt{\frac{2 \times 10\mu A}{332\mu A/V^2 \times \frac{0.2}{0.108}}} = 155mV$$

$$\Rightarrow |V_{dsat1b}| = 145mV.$$

$$I_{1b} = \frac{|V_{o-}|}{1K\Omega} = 0.6mA.$$

$$\therefore (\frac{W}{L})_{1b} = \underline{\underline{429.1}}$$

pick $\underline{\underline{L = L_{min} = 0.13\mu}}$ $\underline{\underline{W_{1b} = 34.33\mu.}}$

when $V_o = 0$. $I_{1a} = I_{1b} = 100\mu A$.

$$\Rightarrow (\frac{W}{L})_{2a} = \frac{1}{10}(\frac{W}{L})_{1a} = \frac{1.38\mu}{0.13\mu} \ \#$$

$$(\frac{W}{L})_{2b} = \frac{1}{10}(\frac{W}{L})_{1b} = \frac{3.43\mu}{0.13\mu}. \ \#$$