ELECTRONICS-I

ELEC 311

Answers to past Final examinations

yrs. 2005, 2006, 2007, 2008, 2009

Final'05 ⟨Answers⟩ Aug. 12, 2005

Q1. $A_{vo} = \frac{v_o}{v_i} = \frac{4}{9}$; $R_i = \frac{v_i}{i_i} = 30\,\Omega$

$R_o = -\frac{5}{6}\,\Omega$

Q2: $R = 537\,\Omega$ or lower

Load regulation $= -5\ mV/mA$

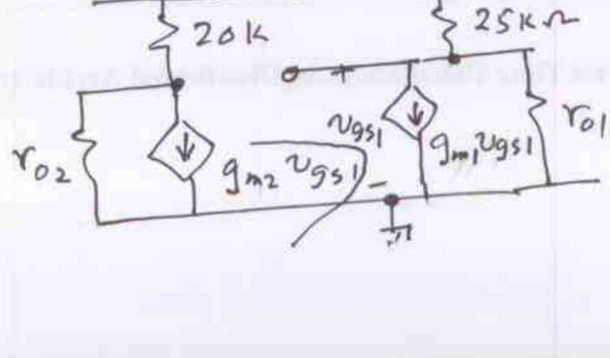
Q3: (a) $v_o = 0.871$ volts (ac)
(b) $v_o = 0.898$ volts (ac)
} need to use iteration to find I_D, then $r_d = V_T / I_D$ ...

Q4: $R_B \approx 160\,k\Omega$, $R_E \approx 7.7\,k\Omega$ are the initial design values for DC operation.

Q5: $R_{in} = 21.79\,k\Omega$, $R_{out} = 165\,\Omega$, $\frac{v_o}{v_{sig}}$ = close to 1 but less than (CC stage)

largest output signal level 5 V peak.

Q6: $R = 25\,k\Omega$; $I_{D2} = 120\,\mu A$



Final '06 ⟨Answers⟩ Aug. 22, 2006

Q1: (a) $v_D = 0.664\text{V}$; $I_D = I_R = 0.434\text{ mA}$

(b) $v_D = 0.66\text{V}$; $I_D = 0.434\text{ mA}$.

Q2: (a) $C \simeq 2562\ \mu\text{F}$

(b) 15.12 V

(c) $\Delta t = \tau = 0.678$ msec.

Q3: (a) $V_E = -0.5\text{V}$; $V_C = 4.5\text{V}$

(b) $V_B = -0.5\text{V}$; $\geq 2.4\text{V}$ (saturation.. assuming $V_{CE(sat)} = 0.2\text{V}$.)

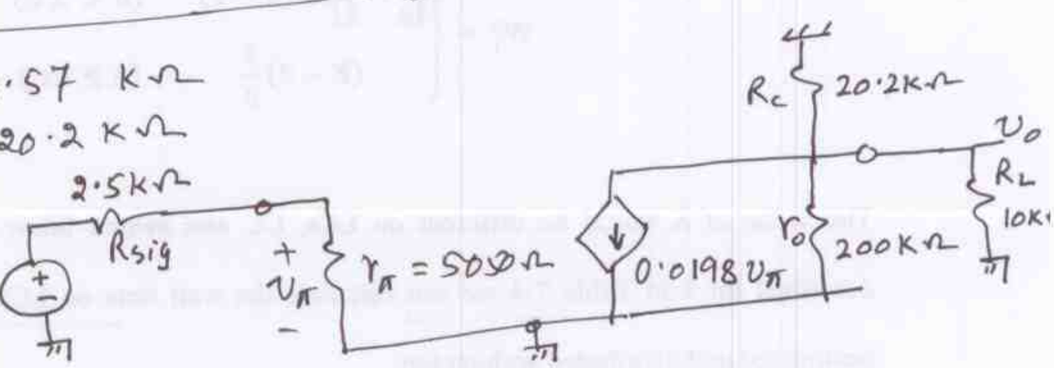
(c) For cut-off, $V_E = -1\text{V}$, $V_C = 5\text{V}$

For saturation $V_E = 1.9\text{V}$, $V_C = 2.1\text{V}$

Q4: (a) $R_E = 28.57\text{ k}\Omega$

(b) $R_C = 20.2\text{ k}\Omega$

(c)



(d) $\dfrac{v_o}{v_{sig}} = -85.73$ V/V

Q5: (a) $R_{in} = 75.76\ \Omega$

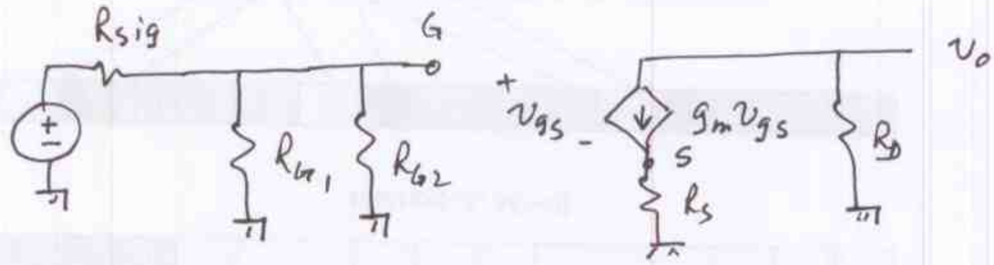
(b) $v_o / v_{sig} = 9.68$ V/V

(c) $v_{sig} \leq 50$ mV

Q6: (a) $I_D = 1.697\ mA$

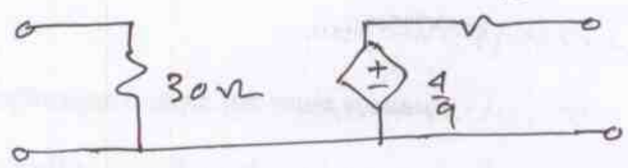
(b) $\frac{v_o}{v_{sig}} = -3.55\ V/V$

ac equiv. ckt:



Final '07 ⟨Answers⟩ Aug. 15, 2007

Q1:



$R_i = 30\Omega$; $R_o = -5/6\ \Omega$; $A_{v_o} = \frac{4}{9}$ V/V

Q2: Case I: $v_o = 0.871$ volts

Case II: $v_o = 0.898$ volts.

Q3: Same as Q.3, Final '06

Q4: Same as Q 5, Final '06

Q5: Same as Q 6, Final '06

Q6: Same as Q.6, Final '05

Final '08 ⟨Answers⟩ Aug. 20, 2008

Q1:
(a) 15.57 V

(b) 47.4 % → $\frac{170.53^\circ}{360^\circ}$ for each diode

(c) $I_{Avg.} = 9.4$ mA (note: $V_{DC} = \frac{2E_m}{\pi} - 1.4$ V).

—— o ——

Q2: $V_E = 0 - 0.7V$; $I_E = 0.93$ mA
$I_B = 18.23\,\mu A$, $I_C = 0.912$ mA; $V_C = 5.44$ V

—— o ——

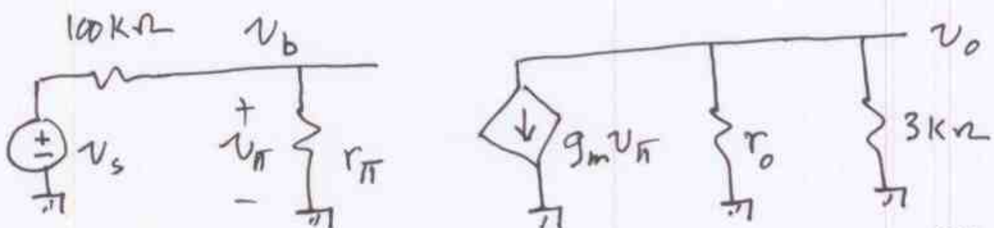
Q3:
(a) $V_C = 0.995$ V

(b) $V_B = 2$ V

(c) $R_{in} \approx 500\,\Omega$

—— o ——

Q4:
(a)



$r_o = 43.48$ kΩ; $r_\pi = 1086.96\,\Omega$; $g_m = 92$ m℧

(b) $\frac{v_o}{v_s} = -2.78$ V/V

(c) $v_s < 0.86$ V

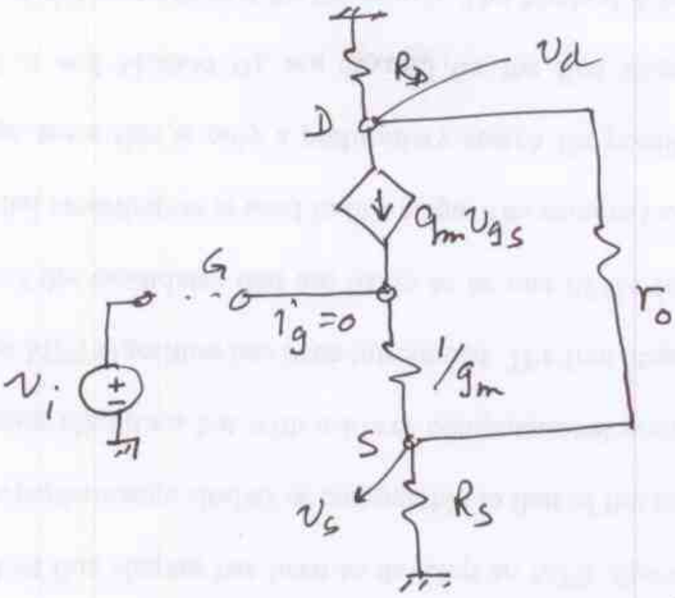
—— o ——

Q5: $R_D = 5.33$ kΩ; $R_S = 5.33$ kΩ; $R_{G1} = 1.63$ MΩ
$R_{G2} = 3.37$ MΩ

—— o ——

Final '08 < Answers >

Q6: AC equivalent circuit model..



Assuming $r_o \to \infty$,

$$\frac{v_s}{v_i} = \frac{g_m R_s}{1 + g_m R_s} \quad (a)$$

$$\frac{v_d}{v_i} = -\frac{g_m R_D}{1 + g_m R_s} \quad (b)$$

If $r_o = \infty$ is not assumed

$$\frac{v_s}{v_i} = + \frac{g_m g_D}{(g_o + g_D)(g_s + g_m + g_o) - g_o(g_m + g_o)} \quad (a)$$

$$\frac{v_d}{v_i} = -\frac{g_m(g_s + g_m + g_o) - g_m(g_m + g_o)}{(g_o + g_D)(g_s + g_m + g_o) - g_o(g_m + g_o)} \quad (b)$$

<note: $g_o = \frac{1}{r_o}$; $g_D = \frac{1}{R_D}$; $g_s = \frac{1}{R_s}$ >

Final '09 <Answers>

Aug. 14, 2009

Q1: (a) 18.527 kΩ

(b) $I_Q = 149.85 \mu A$
$V_Q = 0.023$ V using given formula.

Q2: (a) $R \approx 318 \Omega$

(b) 6.47 V

Q3: (a) 3.2 mF.

(b) 19.56 V

(c) 12.84°

Q4: (a) 28.575 kΩ

(b) 20.2 kΩ

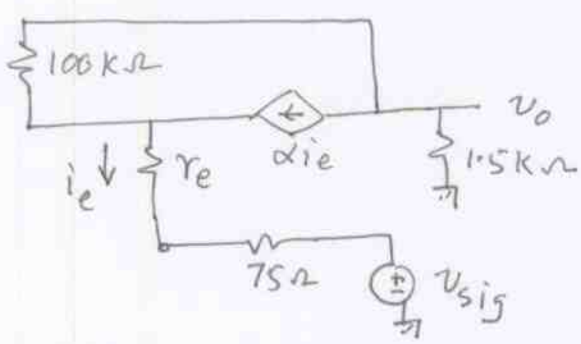
(c) −66.26 V/V

Q5: (a) 97.5 Ω

(b) −17.91 V/V

(c) −86.73 V/V

Q6: (a)



(b) 9.7 V/V

(c) 49.75 mV

Q7: (a) 2.086 mA

(b) −12.12 V/V.

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ELEC 311 Summer 2012

Final Exam

soln. – ~~Part~~ I

Q 1:

$V_{GS2} = 0.7V, \quad V_{ov_2} = 0.2V.$

$I_2 = 0.5\,mA \cdot \left(\frac{4}{2}\right) \cdot V_{ov}^2 = .5 \times 2 \times .04 = .04\,mA$

(a) So $R_1 = \frac{1.8 - 0.7}{.04}\,k\Omega = \frac{1.1}{.04}\,k\Omega = 27.5\,k\Omega$

(b) At the edge of saturation, ~~$V_{D1} \approx V_{G1} = V_G$~~

$V_{DS}|_1 = V_{ov1} = V_{ov2}$ ($\because$ gates are connected)

$= 0.2\,V = V_{D1}$ ($\because$ source grounded)

$I_1 = I_2$ $\because$ identical transistors, identical V_{GS} values

So $I_1 = .04\,mA = 40\,\mu A.$

$R_2 = \frac{1.8 - .2}{.04}\,k\Omega = 40\,k\Omega$

(c) $I_1 \Big|_{\text{Early effect}} = I_1 \left(1 + \frac{V_{DS1}}{V_A}\right)$

$= .04\,mA \left(1 + \frac{.2}{50}\right) = 40.16\,\mu A$

——— x ———

Q2: Using $V_2 = V_1 + 2.303\, n V_T \log_{10}(I_2/I_1)$

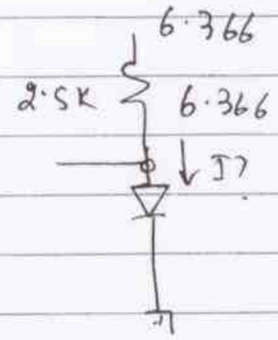
with $I_2/I_1 = 10$, $V_2 - V_1 = 100$ mV.

So $100 \text{ mV} = 2.303\, n \times 25 \text{ mV}$

$$n = \frac{4}{2.303} = 1.7368$$

~~Given: $V_2 = V_1 + .099 \log_{10}(I_2/I_1)$ ← given law~~

For 10 V peak; $V_{DC} = \frac{10 \times 2}{\pi} = 6.366$ V.



Iteration:

Say $V_D = 0.7$ V ~~@ I = 1mA~~

~~$V_2 = 0.7 + .099 \log_{10}\left(\frac{I_2}{1}\right) = 0.7 + .099$~~

$$\log_{10}(I_2) = \frac{V_2 - .7}{.099}$$

$$I^{(1)} = \frac{6.366 - .7}{2.5K} = 2.266 \text{ mA}.$$

$$V_2 = .7 + .099 \log_{10}(2.266) = 0.735$$

$$I^{(2)} = \frac{6.366 - .735}{2.5K} = 2.252 \text{ mA}$$

$$V_2 = .7 + .099 \log_{10}(2.252) = 0.735 \text{ V}$$

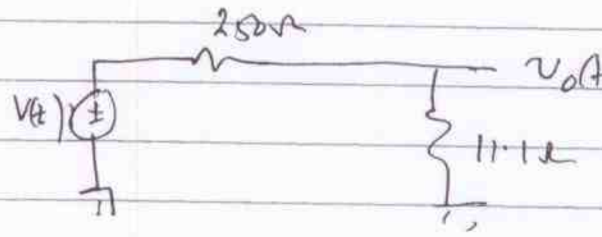
Convergent

Q2:

$I = 2.252\ mA$

$r_d = \frac{25\ mV}{2.252\ mA} = 11.1\ \Omega$

ac equivalent circuit:



$v_o(t) = \frac{11.1}{261.1} V(t),$

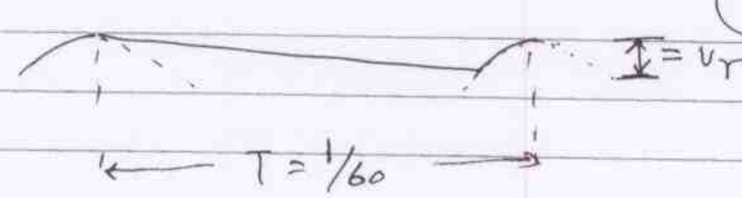
$v_d(t)\big|_{peak} = 0.425\ V.$

So $v_o(t) = 0.425\ \sin(\omega t)$

——— x ———

Q3: Peak value at secondary winding $= 15 \times 1.414$
$= 21.21\ V$

Peak value at the filter capacitor $= 21.21 - 2V_{DO}$
$= 21.21 - 1.6 = 19.61\ V$



(a) Using charge conservation principle, the ripple V_r is given by:

$C V_r$ = charge up $\simeq \frac{V_P}{R} \cdot \frac{T}{2}$ = discharge

$C = \frac{V_P T}{R V_r} = \frac{19.61 \times 1/60}{200 \times 0.5} =$ ~~3.268~~ mF ~~1.134~~ 1.634 mF

Q 3(b) $= \frac{1}{2\pi}\left(6.4\theta_1 - 1.6\times 3\pi\right) = \frac{-14.596}{2\pi} = -2.323V.$

3(b) From the symmetry of the rectified waveform, the output DC will be:

$$v_o\Big|_{DC} = \frac{1}{\pi}\int_{\theta_1}^{\pi-\theta_1}(21.21\sin\phi - 1.6)\,d\phi$$

$$= \frac{1}{\pi}\cdot\left[21.21.\ \cos\phi\Big|_{\pi-\theta_1}^{\theta_1} - 1.6\ \phi\Big|_{\theta_1}^{\pi-\theta_1}\right]$$

$$= \frac{1}{\pi}\left[2\times 21.21\cos\theta_1 - 1.6(\pi - 2\theta_1)\right]$$

$$= \frac{2\times 21.21}{\pi}\cos\theta_1 - 1.6\,\frac{\pi-2\theta_1}{\pi}$$

$V_{DC} = \frac{V_p + V_p - V_r}{2} = V_p - \frac{V_r}{2} = 19.61 - .25 = 19.36V$

Subst. θ_1 value of 0.0755 rad.

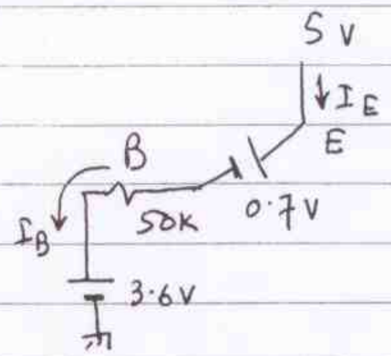
$$v_o\Big|_{DC} = 11.94 \text{ volts.}$$

3(c) The PIV rating for each diode should be $V_s - V_D$
$= 21.21 - .8 = 20.41$ volts.

3(b) $V_{DC} = \frac{V_p + V_p - V_r}{2} = 19.36\,v.$

Q4: We need to find the 'ac' parameters, g_m, r_π, r_o.
DC bias current need be calculated.

The EB loop is :



Thus $5V - 0.7V - 50K \times I_B - 3.6V = 0$

So $I_B = \frac{5 - 4.3}{50K} = 14\ \mu A$

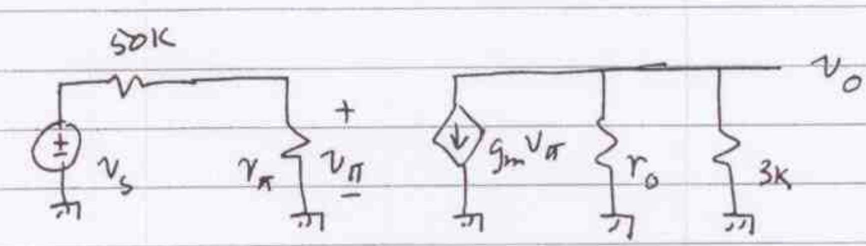
Then $I_C = 14\mu A \times 80 = 1.12\ mA$

$g_m = \frac{1.12\ mA}{25 mV} = 0.0448\ ℧ = 44.8\ m℧$

$\therefore r_\pi = \frac{\beta}{g_m} = \frac{80}{.0448} = 1785.71\ \Omega$

$r_o = \frac{50}{1.12}\ K\Omega = 44.64\ K\Omega$

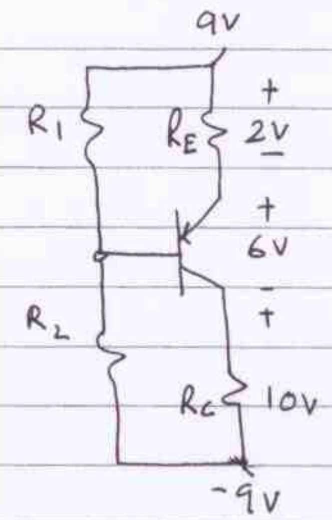
The ac equivalent circuit is:



$\frac{v_o}{v_s} = -g_m \cdot \frac{r_\pi}{50K + r_\pi} \cdot r_o \parallel 3K$ = ~~$-.0448 \times \frac{1785.71}{50K + 1785.71} \times$~~

$= -.0448 \times \frac{1.786\ K}{51.786 K} \times (44.64K \parallel 3K) = -4.34\ V/V.$

Q5: The specified DC values on the schematic are:



$\because I_{CQ} \cong .5\ mA$ and $V_{R_C} = 10\,V$; $R_C = \frac{10}{.5}\,K\Omega = 20\,K\Omega$

$$I_{EQ} = \frac{\beta+1}{\beta} I_{CQ} = \frac{100}{99} \times .5mA = ~~5.05\ mA~~\ 0.505\ mA$$

$$\text{Then } R_E = \frac{2V}{~~505mA~~} = \frac{2V}{.505\ mA} = 3.96\ K\Omega$$

For R_1, R_2 design, we find

V_{BX} = Thev. voltage at base

$$= 9\frac{R_2}{R_1+R_2} - 9\frac{R_1}{R_1+R_2} = 9 \cdot \frac{R_2-R_1}{R_1+R_2}$$

R_{BX} = Thev. equivalent resistance $= \frac{R_1 R_2}{R_1+R_2}$

Let $R_2 = mR_1$ with $m > 1$

$$V_{BX} = \frac{9(m-1)R_1}{(m+1)R_1} = \frac{9(m-1)}{m+1}$$

$$R_{BX} = \frac{mR_1}{m+1}$$

KVL @ the EB loop gives

$$7V - 0.7V - I_B\frac{mR_1}{m+1} = \frac{9(m-1)}{m+1}$$

Q5: But $I_B = \frac{0.5mA}{99} = 5.05\mu A$

So

$$6.3 = 5.05\times10^{-6} \times \frac{mR_1}{m+1} + 9\,\frac{m-1}{m+1}$$

Let $m = 2$

$$6.3 = 5.05\times10^{-6}\,\frac{2R_1}{3} + \frac{9}{3}$$

$$R_1 = \frac{3.3\times3}{2\times5.05\times10^{-6}} = 980.198\ K\Omega$$

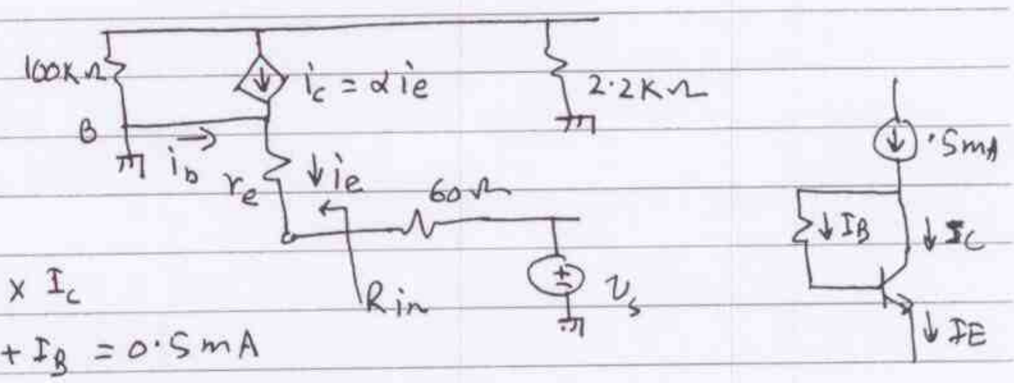
$$R_2 = mR_1 = 1.96\ M\Omega \text{ (approx.)}$$

Basically, $$R_1 = \frac{6.3 - \frac{9(m-1)}{(m+1)}}{\frac{m}{m+1}\times 5.05\times10^{-6}}$$

$$= \frac{6.3(m+1) - 9(m-1)}{m\times5.05\times10^{-6}}\ \Omega$$

& $R_2 = mR_1\ \Omega$

Q6: This is a CB-BJT amplifier with ac equivalent circuit as:



$$I_E = \frac{101}{100}\times I_c$$

$$= I_c + I_B = 0.5mA$$

So $r_e = \frac{25mV}{.5mA} = 50\Omega$

Q6: Since V_A is not given, we take $r_o = \infty$.

(a) By inspection, $R_{in} = r_e = 50\,\Omega$

(b) The output signal voltage

$$v_o = -\alpha i_e \cdot (100k\Omega \,\|\, 2.2k\Omega) \simeq -\frac{100}{101} \times 2.2k\Omega \times i_e$$

But $i_e = -\dfrac{v_s}{(60+50)\,\Omega}$

So $\dfrac{v_o}{v_s} = \dfrac{100}{101} \times 2.2k \times \dfrac{1}{110} = 19.8$ V/V

(c) For small signal approximation to be valid

$v_{re} < 25$ mV

i.e. $v_s \cdot \dfrac{r_e}{60\Omega + r_e} < 25$ mV

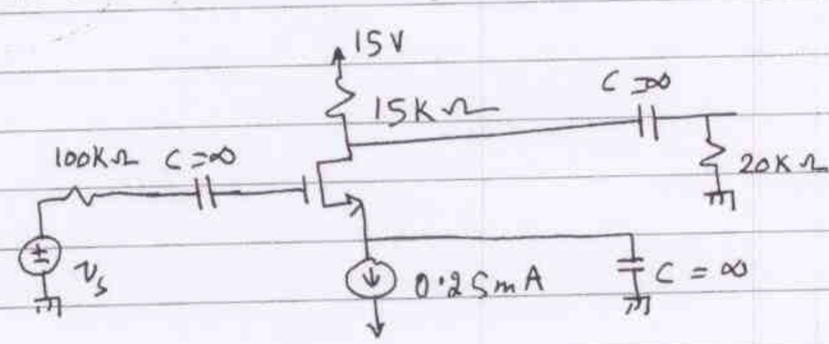
$v_s < 25 \times \dfrac{110}{50}$ mV $\rightarrow 25 \times 2.2$ mV (peak).

$= 55$ mV (peak)

$v_s \ll 55$ mV (peak)

Q7:

(a) Schematic



(b) For the voltage gain we need $g_m = k_n \frac{W}{L} V_{ov} = 1.67$ mA/V

$I_D = .25$mA $= k_n \cdot \frac{W}{L} \cdot \frac{V_{ov}^2}{2}$; $k_n \frac{W}{L} = \frac{.5}{V_{ov}^2}$ mA/V^2 = 5.55 mA/V^2

$r_o = 200k\Omega$; $R_L = 15k \| 20k \| 200k$; $v_o/v_s = -13.72$ V/V

Q 8: Identical transistors; series connection.

→ So $I_{D1} = I_{D2}$ & hence $V_{GS1} = V_{GS2}$

For M2:

$$I_{D2} = \frac{1}{2} K \frac{W}{L} (V_{OV2})^2$$

$$V_{OV2} = 0 - V_1 - 1 \quad \text{while}$$

$$V_1 = -2.5 + I_{D2} \quad \text{where } I_{D2} \text{ is in mA.}$$

So $I_{D2} = \frac{1}{2} \times 3 \times (0 - 1 + 2.5 - I_{D2})^2$

Solve for I_{D2} - quadratic eqn.

→ accept $I_{D2} = .78$ mA

→ Then $V_1 = -2.5 + .78 = -1.72$ V → Ans # 1.

$V_{GS2} = 0 - V_1$ ~~-1V~~ $= 1.72$ ~~0~~ $=$ ~~0.72~~V 1.72V

$V_{GS1} = V_{GS2} =$ ~~0.72~~V 1.72V

Then $V_{GS2} = 2.5 - V_2 =$ ~~+0.72~~ 1.72V

~~$V_2 = 2.5 - .72 = 1.78$ V~~

→ $V_2 = 2.5 - 1.72 = 0.78$ V Ans # 2.