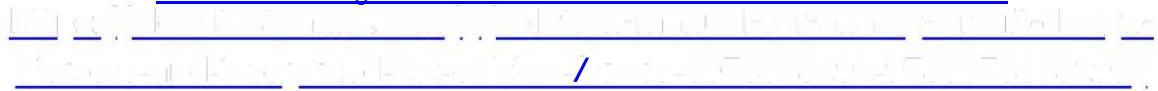


# Solution Manual for Analog Circuit Design Discrete and Integrated 1st Edition Franco 0078028191 9780078028199

Full link download

Solution Manual: <https://testbankpack.com/p/solution-manual-for-analog-circuit-design-discrete-and-integrated-1st-edition-franco-0078028191-9780078028199/>



2.1

Two conditions are necessary for successful BJT operation: (a) the emitter must be doped much more heavily than the base; (b) the emitter and collector must be separated by a thin contiguous base.

In the case of two discrete diodes, it is not known *a priori* whether (a) is met; (b) is certainly not met, as the two anodes are not contiguous; the holes injected from the emitter-acting anode would rather recombine with the electrons supplied by the "base" wire, than progress towards the collector-acting anode.

In the case of two half-BJTs, condition (a) is met, but condition (b) still isn't, as the two base regions, though thin, are not contiguous, but separated by interconnecting wires. The electrons supplied by those wires will recombine with the holes injected by the emitter, resulting in virtually zero collector current. Thus,  $\beta_E \approx 0/I_B = 0$ .

2.2

$$(a) I_s = 10 \times 20 \times 10^{-8} \frac{1}{10^4} 2 \times 10^{20} \frac{1}{100} g @ 9 \text{ & c.usf#}$$

$$\beta_F = \frac{\frac{1}{18} \frac{1}{10/1}}{\frac{1}{28150} \frac{1}{8} \frac{1}{100} \frac{1}{510}} = 351$$

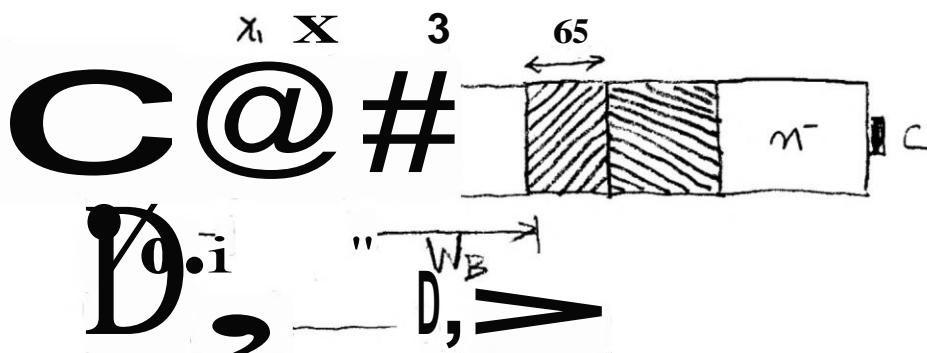
(1 - 0.16) ex (700/e) - \$0.8A

$$Te = I / + 5\% - 8/45 = 1/2 \% A.$$

$$c 10\% = 908/000 = 57 \text{ a} 7 = 668/0 = 105 \text{ A.}$$

[23] @)  $\rho e - s \sigma (h+) y - O, - \beta Vee$   
 $F, / + \Delta - 250 = 50$   
 $\frac{500}{500} \cdot \frac{y?}{2G^2} - \frac{W?}{2015067} \Rightarrow Wg - l O \rightarrow$

L,  $\frac{\rho e}{500} \frac{NW}{DNe W} - \frac{8il}{18 \times 10^6 We} @ 4 ti's > We - 0.520 a.$



$h \cdot 6 \frac{10 \cdot 100}{2} F^4 \gg, \quad \} = 700 \gg v$

, ,  $= -/ sde - \frac{wg}{@e Nasr + N} \sqrt{108} m$   
 $108 \gg m$   
 $1GT, jot? 1j7no''?$

$\chi - \#it? e - "A = a \ll$

$$x_{30} = \sqrt{\frac{2 \times 10^{-12} \times 0.7}{1.6 \times 10^{-19} \times 10^{17}}} \frac{10^{15}}{10^{17} + 10^{15}} = 9.4 \text{ mm}$$

$$D_1 = W_E + x_1 = 520 \text{ mm} + (1.1 \text{ mm}) \sqrt{1 - \frac{0.7}{0.94}} \approx 520 \text{ mm.}$$

$$D_2 = W_B + x_2 + x_3 = 1,039 \text{ mm} + (108 \text{ mm}) \sqrt{1 - \frac{0.7}{0.94}} + \\ + (9.4 \text{ mm}) \sqrt{1 - \frac{-2}{0.7}} \approx 1,039 + 55 + 18 = 1,112 \text{ mm.}$$

2.4

$$(a) I_s = (25 \times 10^{-4})(50 \times 10^{-4}) \frac{1}{10^{-4}} \times 2 \times 10^{20} \frac{1.6 \times 10^{-19}}{10^{17}} 8 = 0.32 \text{ fA.}$$

$$\beta_F = \frac{1}{\frac{3}{8} \frac{10^{17}}{10^{19}} \frac{1}{1} + \frac{(10^{-4})^2}{2 \times 100 \times 10^{-9} \times 8}} = \frac{1}{\frac{1}{267} + \frac{1}{160}} = 100$$

$$(b) I_s = \frac{K_1}{W_B} \Rightarrow I_s \text{ doubles to } 0.64 \text{ fA.}$$

$$\beta_F = \frac{1}{K_2 W_B + K_3 W_B^2} \Rightarrow \beta_F = \frac{1}{\frac{0.5}{267} + \frac{0.5^2}{160}} = \frac{1}{\frac{1}{533} + \frac{1}{640}} = 291.$$

$$(c) I_s = 0.32 \text{ fA (unchanged).}$$

$$\beta_F = \frac{1}{K_3/W_B + 1/160} = \frac{1}{\frac{1}{267} \times 2 + \frac{1}{160}} = 123.$$

$W_B$  affects both  $I_s$  and  $\beta_F$ , and halving it will double  $I_s$  and increase  $\beta_F$  by more than a factor of 2.  
 $W_E$  affects only  $\beta_F$ , and doubling it will halve the B-E diffusion component of  $I_B$ , thus increasing  $\beta_F$ .

$$5 @ 1e \text{ H}_3 - A, V_e = 0.4 - \frac{40}{40.5} - 0..x2 \text{ f}$$

$$e^{-\frac{4}{4}} = 1.005 \text{ A}$$

$$+ \frac{1}{710 \sqrt{4717}} \approx \frac{0.095}{71} = 8^{1/4}$$

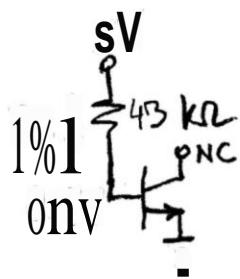
$$Tc | e - l e - 1005 - 0.00 \text{ f} = 0.99 \text{ A.}$$

$$(1) I_{es} = 0.0010 \cdot 8^{1/4}; Tse \text{ A.}$$

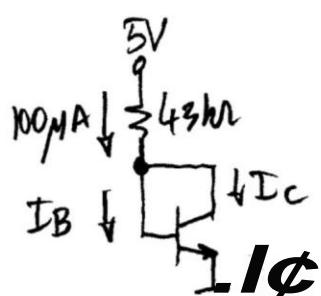
$$\rightarrow Z_c = 0, 1\% - IE \text{ eIK}$$



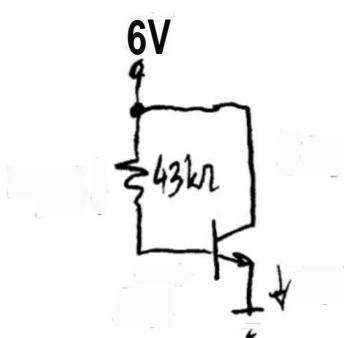
2.6



$I = 7, -ooh = e. = 0$   
 b, heh ) A }, -He P  
G, uA t h d, tied. s P { po » g  
 O t.



$Ie = 100nA ( ) 0A h, ho \approx 6,$   
 $n / < 1A lodeho 6t. < )$   
 $Ic + J = 100E + V = 10O A$   
 $> 7 nA ( \% 00 \{ so BE + ho,$   
 $\% / 80n, recombining \} ai d e. ans rt \gg ? ).$   
**E1#A** ( s t u n s hes Eto BtQ).



$U_0 = U_{BE} + I_C R_C$   
 $T - I_{MAX} \{ hon Bt \{ \% o$

**a e**  $I = I_e = 100I - 10mu (@echo$

$ho \# B). Ve = etc - 10m$   
 $(stL,, hbass \{ \} Etc).$

[27]  $\text{a} = -5\text{-}O\% = -5.8\text{V}$ ,  $1 \neq T \neq 50A$   
 $2 = 1e/(0,+) = 500/81 = 6.2\text{mK}$ ,  $Z_c = I_C T = 40\text{A}$ .

**S**  $(O\mathbf{O} = \tau; \mathbf{G} = \mathbf{O}\mathbf{h} = O + e) =$   
 $1 + 0.2t + (6us^2j) - I_s = S - 44.2A$   
 $(i_o - 0) i_o = 10a, -I_u = -10.07\%$   
 $\mathbf{h}[(on6)/(O')] = -70; \mathbf{i}_o = 10 +$   
 $(9 i_o > 50k) la O_{33}h, 5r_0 L 6.7\% V$   
 $(@) do 80m, R^2 = 0.7uh, O = -0.075 - 875\%$

$i_v] @ yie = ea 00/0 - \sqrt{5}A; = -\frac{5}{10 \times 5}$   
 $e 2j @ c > 100tu - 2.413 mu\#.$   
 $R_t - C [i. 53. g? + "g' \tau u - m -$   
 $(e 2. sooa (= 26285), irl';$   
 $C1 + 13\% 1 2(18+18)0? = s.18 vV$

$@cc > 2A (1\% t5); O. 388A.$

$P. 10 + 1.34 + 2(18+18+8r8)1? = 10'to V$

$$\frac{1}{210} \partial \mathbf{J}_{\text{at ea}} = \frac{1}{4} \cdot \frac{\partial \mathbf{r}_{i0}}{\partial \mathbf{q}} \cdot \frac{\partial \mathbf{J}_i}{\partial \mathbf{q}}$$

$$e_i = 100 \times 0.4604 M_k$$

$$Dr = -1 - 0.006 \left[ \frac{6.04}{gm} \right]^3 \cdot \frac{m^2 g x_0}{l^3}$$

$$= -1 - (0.70 + 0.84) = -2.567 \text{ V.}$$

(0.6  $\times e_i$ )  $- 5/4 = 1.26 \text{ A} (= 50 \times 0.025)$ ;

$\pm - Ooh > 0.2 \text{ B}$

$$Or = -1V - [(123+00-8)rV + (@41.60-198)\{av - 4-(0765+007) - 2,672\} /$$

$$H = \mu_0 e - r_5 \gamma_{ee} / \sigma' (+z, t) = he_{WT \gg V}$$

$$(S) = (0.008)[(e?/hrs)/(t+5t^9)] \cdot 1.0875 \text{ auh}$$

$$C_{oar} \cdot \{ (+\sqrt{6}) / (r_5 \sqrt{6}) \} - 0.95 \sigma.$$

$$AT - 5 \cdot c / le - 2(29) = +80\% \nabla$$

$$Ve = 7/7 + 50 - 767 N.$$

$$FrO, 7wk = (a4A)(2/le) > 0 Ne = +1 - 60 - H2 N;$$

$$2 - 50 - 25 + 25 V = Onop - 2(5)e - 50 N$$

$$4V \% by - 2 - 60 - 2ml; Ve = 7l - = 60 \% V.$$

$$Neob) = 18 - 2(40 - 9) = 1 \% V; 1e = 72 V.$$



**E1** @306-2n<sup>2</sup>( $p\$/$ )=1We 4so5v.  
91 -(9109)x[+Bs10+5)T<sub>F5</sub>A.  
re(eOK+8ta[(ls)]-53-  
(°) 20 O<sub>K-</sub> 500A 2/lo = 4Ve - +18& 60 - 442% l,  
AT- 16- 9C, AVe = (2»V) - - 10; W<sub>(tO</sub>  
= - H-100=- 1H2al, V %&0-2= 53& Z,  
(U) T=55-2530.¢. " }a\_news p»Pc 6.1.d  
ad 500A) t' use ta00ane ve9, 302=%0  
a.v, n lase it 680 - 60=620al. Ue e &  
aisle.B. err, do, ask t<sub>a</sub> to & t 60aN ls,  
log 1fls Tc, \$1 = low5so  
= 5%

[T] @ S. % \$ = 1 H, Tc = (re = ox?)

= 1100 » A; Vc - Ic - 1c - 21770 = 1.5% V.

@ 9% at g, et 6 80 W We, fps 15 bV tas V.

mi Tc - k(Vee/V), ne 'ho

1.720 = k(+ .5% / 100), I = (+ 5 l00)

I / .70 - (+ 50) / (1 + 15%)  $\Rightarrow$  Ic = 1.78 A.

@ ) 1% = 73 - .50, = pe e = 2-05 •

0.28% W, V = 5 - 10 x 0282.13 V.

[T] @ % . 5 = 2, e = .9, = 3

= Z - 2/0.043 [O.]

7, - 1 — 2a5% / (W) - 2.n% A.

(V a - IV, Te - 2 » P, V = 190 V, T = (5 - 2 - 50) / 1 - @.05 a A

2.05 / 2 = + 2950 / 09) / (1 + 1.0 / %)  $\Rightarrow$  V = 77 /.

(@) - G 2) / 0 - O. A, lg = / 5 - 07 / 0 - 0.3 » A  
= .3 / 0.13 z 2.

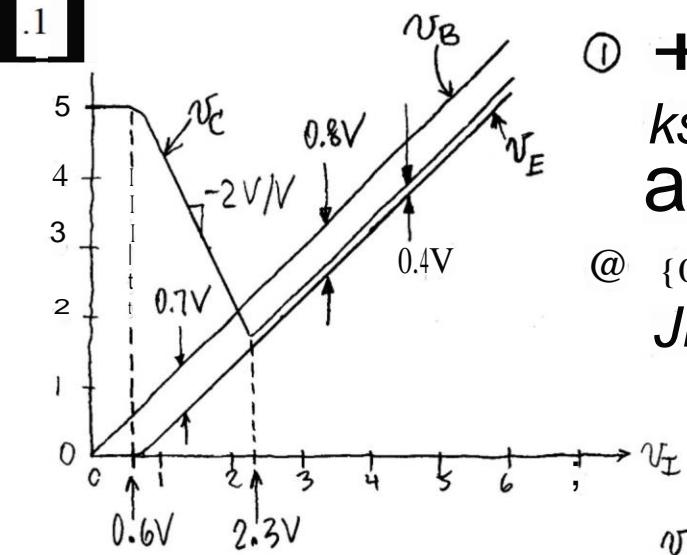


E1a)  $\$ = 5$ ,  
 $p = 5 \text{ or } t = 5 \text{ (sh)}$   
 $55 \text{ £A. } V = AM = 735 = \$0V$   
 $t = 35/0.03 = 5 \text{ years}$   
 $0.5/0.65 = 17.$

" /a)  $CO = 1c - (07-02) = 1.00 \text{ a#}$ ,  
", - 100s/8 - (5.

(b)  $V = \sqrt{O/O} \sqrt{1 - 3.14}$   
We =  $6co - 12.4 \text{ £am. } Tc - 1w, \# L - rzak$   
 $9 = 4a. \cdot s - , \% \cdot ev.$

1

①  $+ @ < V_{CO} \text{ o } \phi y$ 

ks 8122i ct {~,

 $a = I_s > V, dC = 0.$ 

@ {015054 n aloe 0.eV

Jr»» tAT a.

7ala0Ms, t ho

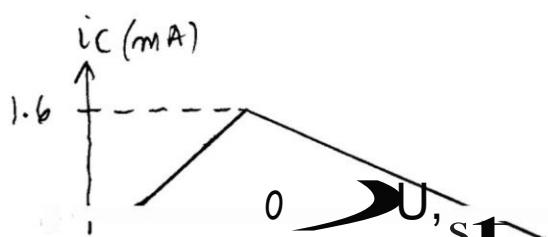
vi rA, done

$$v = s - V_{el} = 0 - 0.7V$$

Megown, C - V - Cdc

zV, -CC - %, -e'

v - Ela, or

 $\phi = 7\% \cdot \{tees - \$; e. (ate, tkw Z te .\$.$ 

AoasI. [-Rahe &gt;-2V//. ip

@ k 5T rah»» ke cos Ra £: 5-(g19, n

 $e = \% v. t 1do Wt, (re e+0 = 18V) de =$  $t + 0.72.3V - k \alpha = (-1&/2 - 1\%) + A$ 

@ A «e » on «wig , tkJala&amp;», Ok

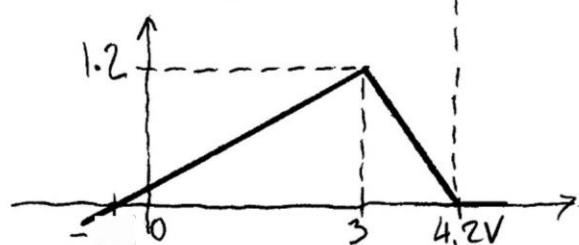
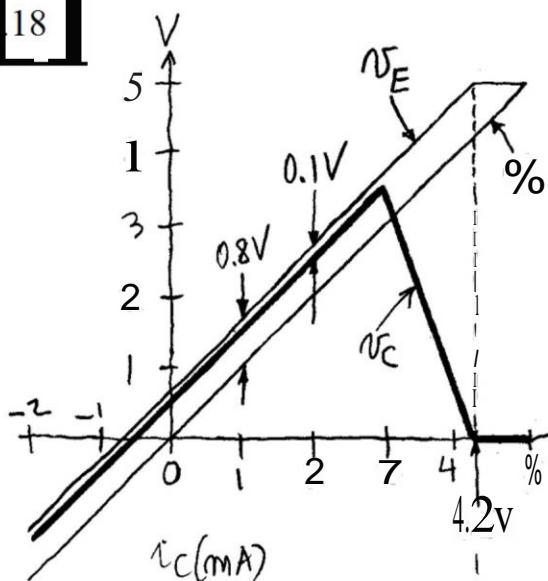
 $a - r - 0.8V_j - e+0., -0V, and \bar{e}$  $(6-e)/2 = [5-(,-02)]/2 = (57->)/. Conk,$   
newd9waneo Wt. AF,,

@) A rAko 5V ic detlo eus. Fd ±&gt;5.7

«c 8com m3sky, %e5-Cuna.a io {oa.A  
lass. ,on»k ic OVO owt4 uModsh !



18



#e  $0h > V - VS (cc2 = 5 - 0.8 - 1.2V, BT = Co)$

$i_C = 0$ ,  $i_C = 0$ ,  
Loron, Oz 1ear  
4.2V  $\rightarrow$  S BJT

$m, \gg \text{otale}, A,$   
 $\text{Z} \& \text{hue}$

$$r_o = +e / I = (r + 0.8V)$$

Meet8n,  $Ur = 0$   
 $r_o = V_{Ra} / S$

= " 2C-0,-08

@ - 3 (42-G.). (eanl, «o  $r_2$  » lone wed below (al,  
We oicce»op adtl.e/s.A+WW, ad. C m o 8  
cttlnsh 4(v/(1y- 'aAN.  $\leftarrow$  C ooo, jUlin.  
0.- } e, tt 6Ado»ta O5. WWK  
— n 3C — (C+08)-0.', e } kdl st

%0 BJ1% tale» tts 605  $\leftarrow$  2.75 3J. 'Attwo

$M \sim C$  4,\$32(2-3)=1.2»A. lo+

cel. r

$\checkmark$  dinwo tli mo?e al mole ts <lnaos,

$\sigma$  re=0e-0.1= +0.8-0.1=  $r + 0.7V$ ,  $i_C > 0$ / $\phi$ =  
(@+077)/(31). 0»e 1; 2»Is onolt» -0.7V, ~cleav»

0,01 Tr mes-(t. U i.kl,ks rs -c

'ynzia)'s <-0.a.

[.19] J, <, ]

I  $g < 0 \text{ V} \Rightarrow \text{BSCo} = C_{zv} S_O, C = 6V,$

$\bullet S > 0.7 \Rightarrow BTO, \text{ will } 0, \text{ FA:}$

$i_e - s8\%, \text{ ff } \geq -D7 \text{ ic-pie } = \frac{I_O}{I_O} = 0.7.$   
 $e = \pm pO - s + 2L = g^2).$

(@) a We noa.dawn, es-Ve~(es)-0. -0.1 = 0.6V, BJT  
 nuadwo eos. th » post,

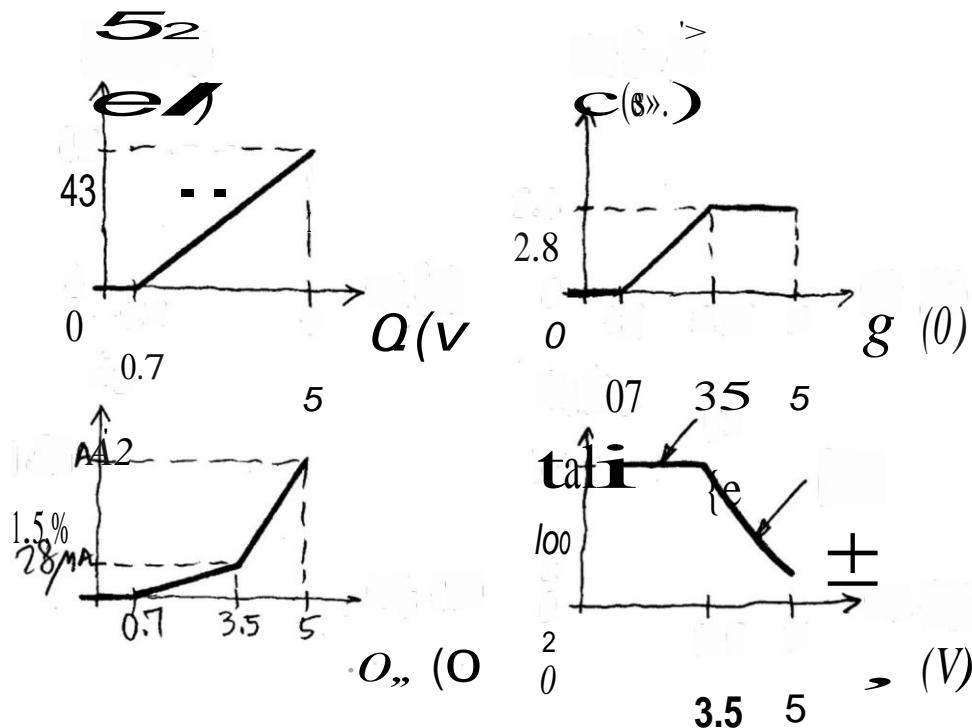
~~eoel-4448%k, Ve9-07+11etee)~~

$07 + P_{bias} = 0.7 + 2.8 - 3.5V; = X; I = 2A.$

+ re, > 35, bJT=Sat :  $ic = C_{os} - 2.8sh,$

$a, -s-07, i, -e - ic = -0.72.8 - (T) - 35\% \#.$

$T_C = \frac{2.8}{I} \cdot \frac{2.8}{U_8} \text{ m. } U_8 = \frac{2.8}{0.7168}.$



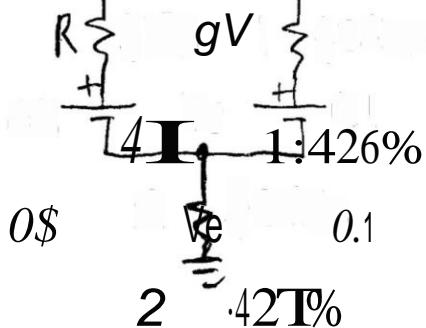


[.2] @

wvl:  $V_{CZ} > (C_1 + I_C e @ E) \times 10r_2 + 2((rs)8;$   
 $kT = fP + V_e / (\kappa \cdot e) = 300 \times 10^3 + 2(10^3);$   
 $\equiv 3 + 1\%, I = O_2 + 2P_2) =$   
 $Z - O_2 > 10$

k

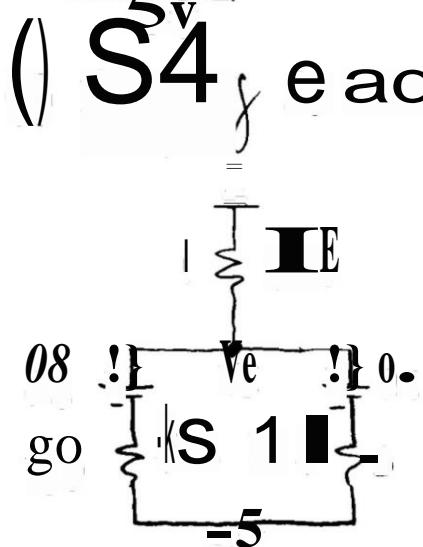
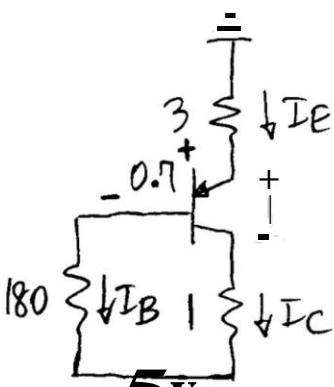
(b)  $L: s = 1tC + 02 + 2Te^{V_E}$  ad  $1C + 02 + 2IE402 + 1C$   
 $= le \cdot 502/3 = 1.0 \mu k$   $2I6 - 2V; V = 32 + 0 =$   
 $3. V; P = 1.6/3 - 1.2, Kef = 3.9 \sqrt{O} = 0.$   
 $(9) / d = o/s = 2\% = Tc \frac{2\%}{V_E} P = 24 \text{ m.}$



$$5 - 1 \times 261 + 0.1 \times 5 \times 1e 1a - 61.25A,$$
$$V_g - 540.062125 + 0.8 = 3.4075V.$$
$$R = (-3.019) / 04175 \Rightarrow 14.0 \Omega$$



# "16[a,&].



we:  $s-3e++1Ic, o$

$$4=3(-)7\% + @r^{\pm} (9=+)s$$

$$\mathbf{vI:5=31c+01+/807\%, o}$$

$$4.3=3(r+)1B+8022=(3pr+183)1\%$$

Tolks patio 94 O bwo 9s:

$$43-\frac{gr?}{3+r183} \Rightarrow \text{rs\&}$$

e ad Re aueo (du BT% slut.

$$E - \frac{9-Ng}{180} = \frac{Ve0g - (9)}{180} + \frac{Ve-0.tz5}{7}$$

$$\nearrow Ve = -1237V. Te = 1.237;$$

$$Tc - 1221a Ts = 1\%. 5A.$$

$$+- \text{, } - 7 < 189+).$$

[ ] @ )  $U: \% = V\% \times 100 + 8\% (5\% + 1\%)$ .

1 FA,  $5 = 0 + 20e + 3(1+5)Lg + 1\% = 7$ . @ i t,  
7cl50x.0 > 1,6 u, Fe=1,37 t; kVl:  
Ve  $\rightarrow 0.00 - 0.05al.3\% = 0.37 - @ 13G$ .

$Vd\% \Rightarrow V_{CC}(\cos) - 0.2 V_{O,2} = 0.88i - 0.916 \Rightarrow$   
0.5R,  $\pm 0.5Q$ .

0 - 0.5 = 1 JT - <%> V - 0.1, Ve = 0.8V.

3 g - S - Y.08,  $kO! \times J_0y$   
aw  $Z = 253, C = 1204a$ ,  
0.81  $(st = 1/0.04/0.0253 = +8$   
JT  $\left( \right) vc - 0 = \pm - 0 / > 0\%$

2.23 (a) Assume FA and check. By inspection,  $I_{R_2} = I_B + I_C = (\beta_F + 1)I_B = 15I_B$ . KVL:

$$9 = 20(15I_B) + 100I_B + 0.7 \Rightarrow I_B = 2.66 \mu A, I_C = 15I_B = 0.399 mA, I_E = 15I_B = 0.402 mA. \text{ By KVL again, } V_{CE} = V_C = V_S - R_2 I_E - R_3 I_C = 9 - 20 \times 0.402 - 1 \times 0.399 = 0.567 V > 0.2 V \Rightarrow \text{FA!}$$

(b) Assume saturation, and check. KCL:

$[V_{KCL} \text{ mA}]$ :

$$\frac{9-V_x}{1} = \frac{V_x-0.1}{3} + \frac{V_x-0.8}{100} \Rightarrow V_x = 6.73 V.$$

$$I_B = \frac{6.73 - 0.8}{100} = 59.3 \mu A$$

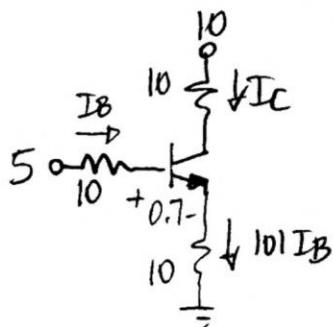
$$I_C = \frac{6.73 - 0.1}{3} = 2.221 mA$$

$$I_E = I_C + I_B = 2.28 mA$$

$$\beta_{sat} = I_C/I_B = 2.221/0.0593 = 37 < 150 \Rightarrow \text{Sat!}$$

2.24

(a)  $[V, MA, kR]$ . Assume FA. KVL:



$$5 = 10I_B + 0.7 + 10(10I_B) \Rightarrow I_B = 4.2 \text{ mA}$$

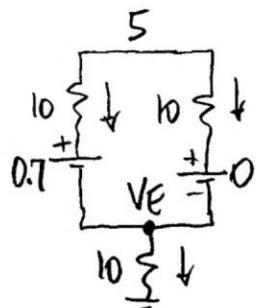
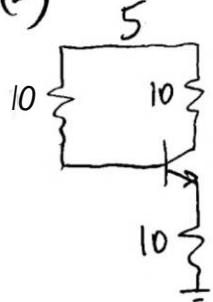
$$I_C = 0.422 \text{ mA}; I_E = 0.426 \text{ mA}$$

$$V_B = 5 - 10I_B = 4.958V; \quad V_E = 4.26V$$

$$V_C = 10 - 10 \times 0.422 = 5.78 \text{ V}$$

$$V_{CE} = 5.78 - 4.26 = 1.52 \text{ V} > 0.2 \text{ V} \Rightarrow \text{FA!}$$

(b)



Now  $B^T \sim \text{slaleA}$ ,

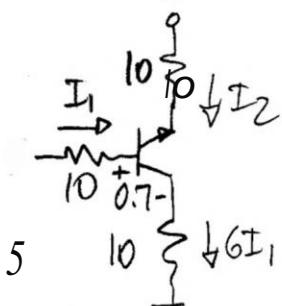
CL

5(e<sup>12</sup>), 5-E • VE

2> Ve=31V.

$T=0.1\%A$ ;  $1\text{p}=0.12\text{m.u.}$ ,  $1=04\text{A.}$   $X+\zeta = 11$   
 $(\text{v})$  &  $voe$   $gcoe$  mole.  $\text{kvL.}$

$$5=101_1 + 07+61_1 = 1= \text{cl. HA}$$

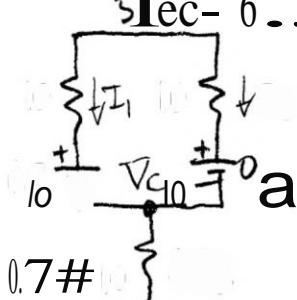
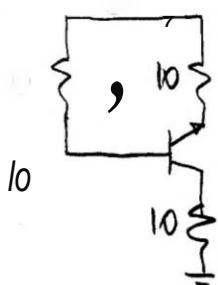


$$7. = 51 = 30 \frac{4}{7} \%, \quad 6 = \% A$$

Ve=8-QJ,- Vc=1-0.7

=3. @V, Ve=O-I0 1, =6.3 V

(d)



BJ7 ko >> p2&e-ode

*lo«las. so!a*

*oi.cad* bo» ox»kcellant t Q,

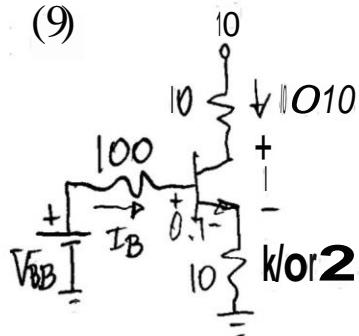
$e^- \cdot v, 1, -0.12R$

72- 0.% ah, 13  
0.1/0.4z = 1.G ·



## [S] [, A, ~].

(9)



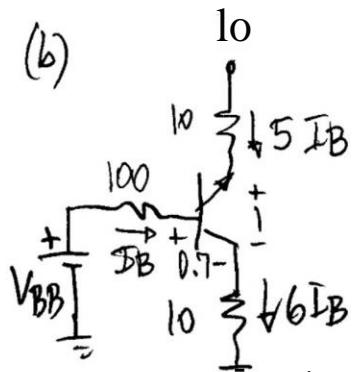
$$V_{U..} = 10 - 10(0.1) = 8 \text{ V}$$

$$= 1\% = 44\% \text{ of } 10 \text{ V}$$

$$V_{CE} = 10 \times 10/I_C = 1.522 V, V_E = V_E + 0.7 V$$

$$= 5.22 V, V_E = 0.7 V + 0.2 V = 0.9 V$$

(b)

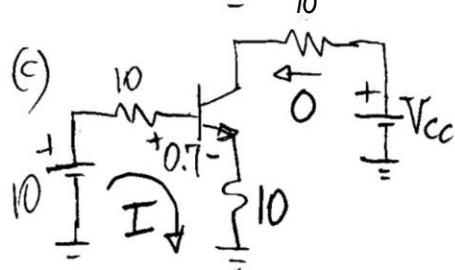


$$V_T = 0 - 10(51) = 49.5 V$$

$$I_E = 81.8 \text{ mA}$$

$$V_E = 0 - 100 \times 0.08 = -8 V, V_C = 5.61 V$$

$$V_E = 5.61 + 100 \times 0.08 = 13.8 V$$



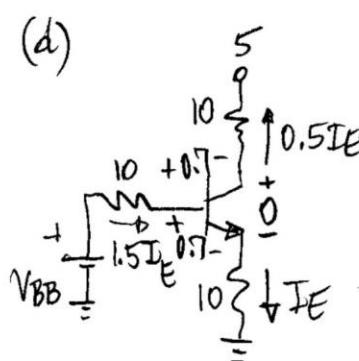
$$COL 1 = I, NL:$$

$$10 \times 10 + 0.7 + 10 = I, I = 0.05 A$$

$$V_E = -4.5 V, V_C = 5.3 V$$

$$O t_C = 0, V_C = 0.65 V, I = 0.05 A$$

(d)



$$I = 15 I_E = T_C - 0.5 I (odd) \text{ colots}$$

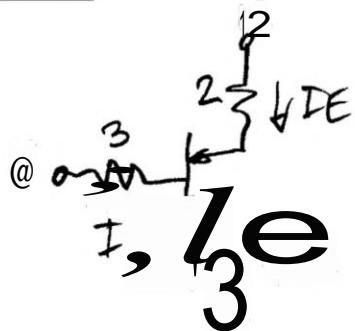
$$\Rightarrow T_C = (0.5 P_A) / (15 I) = 1 < \text{pr % et.}$$

$$- V_{EE} = 0.7 V = O = 5 + 10(0.51)$$

$$> I_E = 10 A \Rightarrow V_a = 10(1.5) + 0.7 +$$

$$10 = 5 V.$$

22 « [ @ [ , a, ] .



Yoe th:  $V_L$ ;

$$|2 - 2x/511g + 07 + 3IE + \%$$

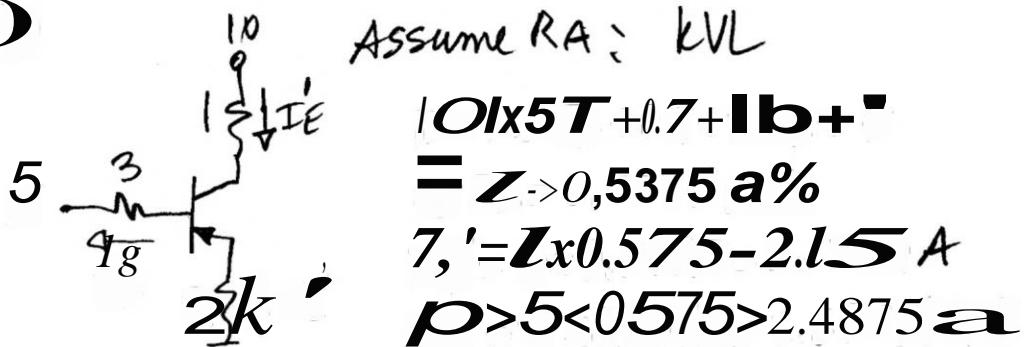
$$R = 7MP, Z = 2.6la,$$

$$- 2.42aA, V = 6O2 V,$$

$$V = 67529 \text{ mV. } C_V$$

VecauV o.1  $\sqrt{cA}$ !

)



Assume RA: kVL

$$|0Ix5T + 0.7 + Ib + |$$

$$= Z \rightarrow 0.5375 a\%$$

$$7, ' = Z \times 0.5375 - 2.15 A$$

$$P > 5 < 0.575 > 2.4875 a$$

$$\% - 5 + 80.5375 - 6.6/25 V; V_C = 6.25m7 = 7.5V$$

$$V_B = 22u5 \checkmark 1.35 - 4 > 0.1e > A ]$$

@)



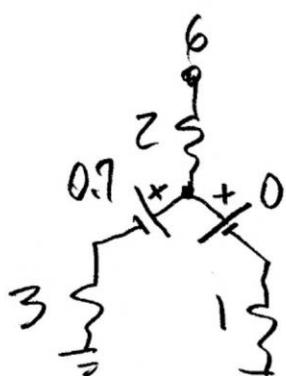
Puna Sb;  $ucL$ ;

$$\frac{0}{Z} - \frac{V_O}{Z}, - O$$

$$V_C = 1.736 V$$

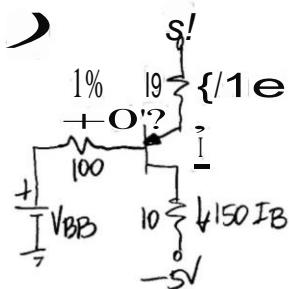
$$I_C = 1.736 mA$$

$$V_B = 1.036 V$$

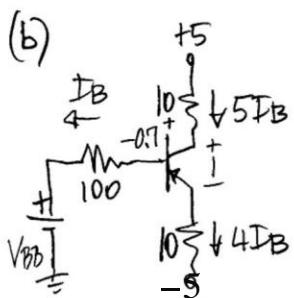


$$I_B = 1.036/3 = 0.345 mA; \beta_{sat} = 1.736/0.345 \approx 5 < \beta_F \\ \Rightarrow Sat!$$

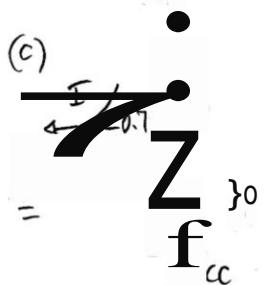
## [2] oat, a



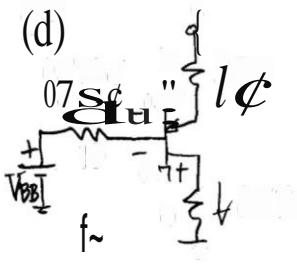
$$\begin{aligned} \text{Ivl: } & s-(s)-\text{lo}(1s1Pe)+\text{lo}(52le) \\ & 7lb = 2.19 \text{ mA} \\ \text{Iau: } & S-\text{lo}(19 \gg)-07-\mathbf{OB} \\ & = -0.51 \text{ V.} \end{aligned}$$



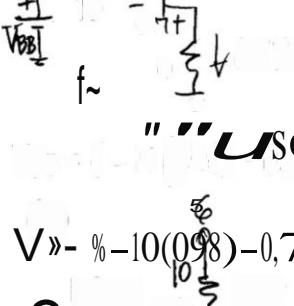
$$\begin{aligned} \text{Ivl: } & 0-(51s)+1+10(412) \\ & = I = 0.4 \gg \\ \text{Iau: } & 1s-5-1(50.)-01-10oxO \\ & = -10.7 \text{ V.} \end{aligned}$$



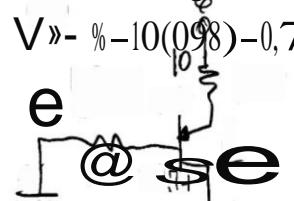
$$\begin{aligned} \text{Ivl: } & kVL: \\ & lo = sv.Fa tc0, st \\ & V_B = 0.415 \text{ mA} \\ & V_{ee} \sim V_{or-D.bS} \sim Lt-15'' + 0., s = 4, w. \end{aligned}$$



$$\begin{aligned} \text{Ivl: } & 1, -0.51 \phi 1c-0 \mathcal{S}, u. \\ & (-Tc/\%) \cdot (512) / 1512 - L \end{aligned}$$



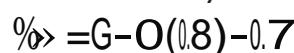
$$\begin{aligned} \text{Ivl: } & 5 < 150 = al. rec o \\ & " " use u: \% - ore + lo (se \Rightarrow) \\ & Ir-08 \& u. VL' \end{aligned}$$



$$\begin{aligned} \text{Ivl: } & T, -L5 \phi I = 0.751 e^{\% l}: \text{ tle} \\ & alta9). Pl-(-47512)[las12 \\ & = O2 < 1s0 = < kale > \\ & V_C = 0. \text{ VL:} \end{aligned}$$



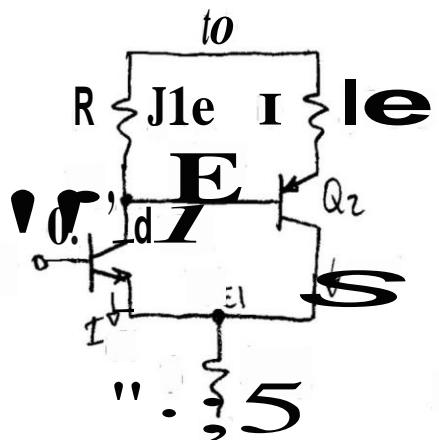
$$\begin{aligned} \text{Ivl: } & V_C = 0. \text{ VL:} \\ & , + o(0.5 Le) - 19 le = jJ \pm 0.8 A \end{aligned}$$



$$\begin{aligned} \text{Ivl: } & \% = G-O(0.8) - 0.7 - lo(1.50.8) = -27 \text{ V.} \end{aligned}$$



[228]  $v_{ce} = L90 - A_1 e_z, \alpha_s = 0.81 \Rightarrow A_v$



$$\begin{aligned} v_{ce} &= V_e - 10 \times 0.51 - v_o, \quad V_L \\ V_L &= 4.07V. \quad V_L = V_e - 0.5V. \quad C_L \\ T_a &= T_a - 1\% = -0.05\%A. \\ W? &\rightarrow e^{\frac{v_o}{0.5}} + 11\% - m\% - 95\% \end{aligned}$$

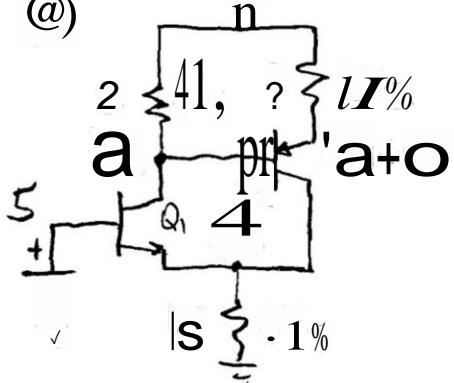
$$0.1 \text{ mA}, \quad R_{in} = 10 \text{ k}\Omega \sim 10 \text{ k}\Omega, \quad V_{ce} = 4.1V - (4 - 0.5) > 0.2V$$

$$= 0 - A_v V_{ce} - \% - (-0.7) > 0. V > G = F_A.$$

$$-1 = \frac{I_C}{P} = (1/52)/55 = 10' \text{ mA.}$$

229 [4k]. As»«eQ, O-=FA, O»d cu-k ve, Va, =

@)



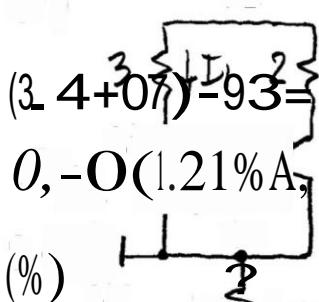
5-07-43V. 170wig,, bane croon»ho,

7,-Te **a** **Ila**, «  
**Iz** 2-Va, r-(Nao.D  
1.5 23 2

Va= 2.uV=lee1,- **R11**=  
n a\_m " " - ~ ~ I - 12-S/4 0,7 =

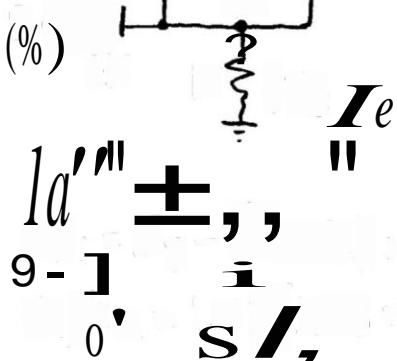
1

1.5nA, **e**-2u-43-.



4 - CZ **an** - 2 ?  
**Coidl**

0,-O(1.21%A, 3.84) <sup>4</sup>, 0a>0. (1.58 570)• V;



karc@**st** Q**7**A, al ck»ck.

Vet-**Ca**= 8-07- 7.3/7, O.3/5=

1» **s** -V»-1.+al=n

We=Va+7= 8.1VI (7-70)/3=

1.53mu, Te-(2-8.)/2= 1.5%h.

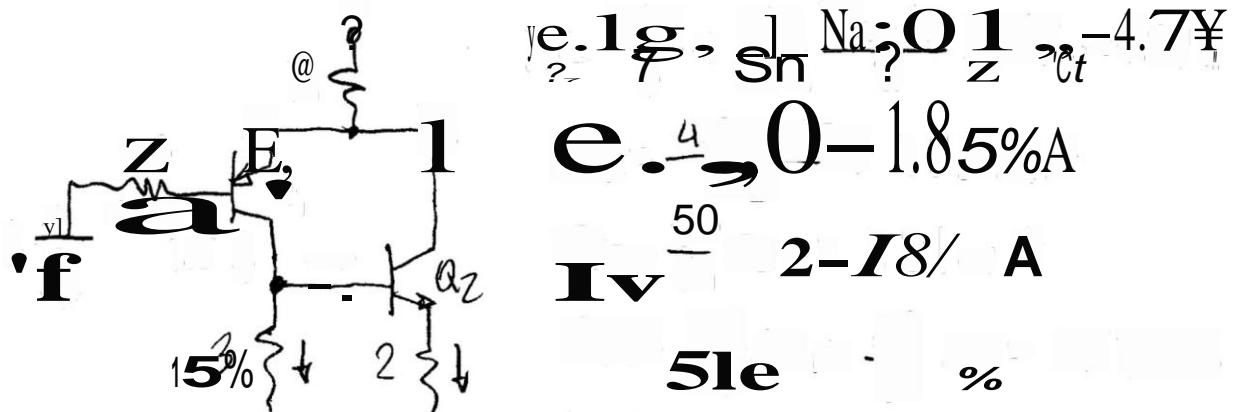
O-O(1.5A, 08V), FA. kcI

Jr-1,-(1,)- 481-(53+115)- 1.38%A. F/en, £

2/1w= 15/18=-1 = 0=t, al O-(1.53%4, 0.1V).



[2.3] @) 1 - A : O : 1 - re - 1% + re2 I()



e. 1g, Sn Na; O 1, -4.7%

e. 0 - 1.85% A

$I_v = \frac{50}{2 - 18} \text{ A}$

5le %

er5r=5is-ta

getcp - 31ank

$I = 70/9 \cdot 6/0 = 0.0$ , Vey- 6+320,0 - 4 - ;  
Ve- V+07 = 1.6, R\_f(12-7.6)/33 €. A. %.

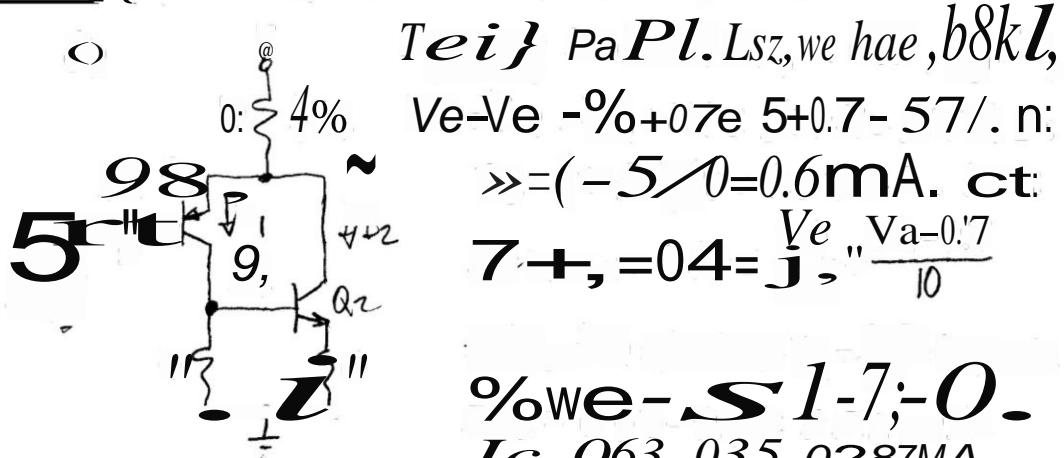
(wh: Ve - (2-13833) - 4.34 £ 33 V > 0 = FA.  
W  $\geq (12-1.3433) - ((3-07) < 4$  O. W A.

O kw ) & zoo. doaoa le mud, vek VS  
olds. tog tko » Dag, .ow - Vows,

Ve 1SSV, Te, is'07) / = 1% h', T, =  
l.s+ - = 3. % k; R, - (12-1.6) / 3.4 = 127 inl. 3k0.

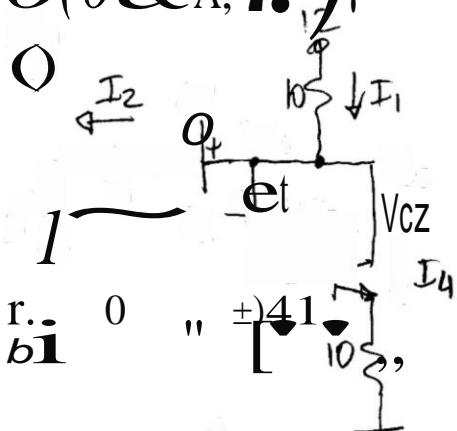


[231] { V,%4 } ]. koms 0O-FA, nu Reh.



%we-S 1-7-O.  
 $J_C = 0.63 \text{ A}$ ,  $I_C = 0.287 \text{ mA}$ .

jea-551-35-2.2V > oV F+,  $V_\ell = -57$ -(5-0.)  
 $\Rightarrow O(0.95A)$ , 18,  $Q_{ye} = 0.95A$ , 2.20);  $02^\circ$   
 $O(0.95A)$ , 18,  $Q_{ye} = 0.95A$ , 2.20);  $02^\circ$



wti R, evkedfo aua,, Te  
 $72e2 = W_{Snell}, 5 \text{ nu}$   
 $P_{vt} = k_{\text{v}} \cdot L \cdot Ar:1 \cdot r \cdot u$

$\Rightarrow dI/dV = aL \cdot Z$   
 $i = 0.8V$ ,  $V_e = 0.7 + 0.8V$   
 $0.8V > 0.1V$  OA.

$$I_k = V_{Vc} \cdot \frac{dI}{dV}$$

$$\frac{1}{10} - \frac{1}{10} = -0.9 \text{ mA}$$

$$1 - .40 \text{ mA} = 0.5 \text{ mA}$$

$= 0.52 \text{ A}$ .  $I_a = 7 = 1 [r. W_g, pez]$   
 $hs. i^2 t \text{ Te} < 0.575 / co5 3\% A$   $P/I < 5.3$

$O_1 O > \langle k. Tu0w \rangle$ ,  $Q = 0$ , ( $< 5.3 \text{ A}, 0.1V$ ), ad  
 $O_2 (0.53\% ah, 0.8V)$ .



---

[3h, , , al. v<sub>z</sub> l, , oh'horpshtdy.

$$V_{cc} = R_C a + V_{az}(eos) + k_s [g \cong (\alpha u + \beta g) C_z + V_{\sim C}(o)] \Rightarrow$$

$$5=22I\phi 2+02 D_z 2=\phi .77 m\#.$$

$$le=1\%.in - (\nabla; Vea= \% 7-07=\% .07V=Ve.$$

$$e-47/0-7.7\phi -$$

$$7a=5-\% 0z)/30 +62.710?=0,3\% 52A. /same Q,A.$$

$$J_r=0.3\% 3/0=3.6\sigma A$$

$$Ve;- V<-1e, =5-10\times 3\% 16 ?4.\% V$$

$$Va-+6-07-3.9 V$$

$$el \cdot I = 0.7 au \pm$$

$$6\%=-9\sqrt{0.37}=105e$$

$$Ve lo21-3,9 >0.2 \gg Q=A.$$

[33] **in G, {vt, rd scone +A. vu@4,**

$$ly = \frac{5-05}{10+10} = 223 \ll$$

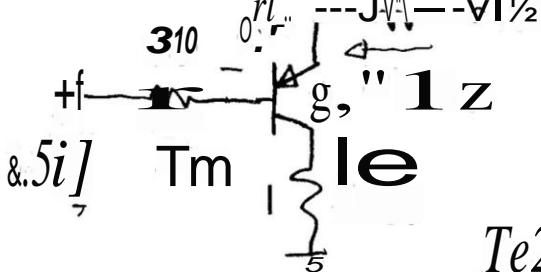
$$V = 5 - 102.0306 > ZV; Wa - 405V$$

$$Tc = 100 \times 0.3 - 0.223 \% A$$

$$la - 15-300.2 - 83 \backslash V$$

lcer- 8.31 - 105, 0 => Q=FA. **let ct:**

$$h \cancel{r} - 0 = FA. \quad e \quad J_{\cancel{r}} = 15-8.3-0' l_{2a4} \cancel{f} A.$$



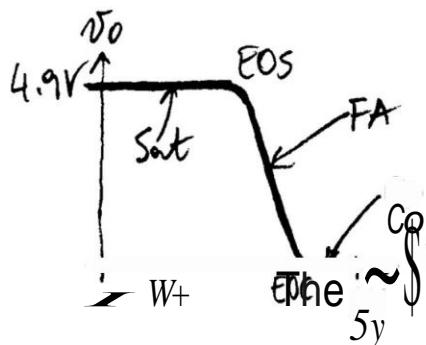
$$Ve = -831 + 0.3 \cdot 46? = ,5V$$

$$ez = 9.9 + 0.7 - 2V$$

$$Te2 \cancel{1} a - 100Be - 9\% \cancel{\#}$$

$$Ve = 1 - \%z + 7. Ve e - 102 - l > z0.2 \Rightarrow = tA.$$

.3 6) sy



Te  $r > V - V_{esc}$  0.5 - 0.6 = 4  $\sqrt{tlo}$   
87 ZOO c $\zeta$  [(. long,  $r$   
hilar UV dcotk, E  $\zeta$  oi. FA:  
Dr, - V-O-Sie  
 $V - \frac{1}{n} \underline{\alpha} / @ - 0a. @ oP$   
 $= 5 - 0.0206\%$ .  $\frac{g}{T^2 N^{15}} IO g_{80}$ , or  
FA  
/ Co  
~ 5y  
O ntaled Ao,  
Vac- Vd ( $s\zeta$ ) - 5 - 0.1 4, a  $\sqrt{.}$

0w>, soc p0.VCS- ; -0oghu(он)=3.628v.  
O=s- #-0026% ("@)- 3.'74% V  
0%# +#%aw E ''##, or  
=-% -00% \$ a - -8@; a] o-v -& 44 W.  
6

2.35

$$(a) KVL: V_I = R_B i_{R_B} + V_{BE} = R_B (i_B + \frac{V_{BE}}{R_{BE}}) + V_{BE} = R_B i_B + (1 + R_B/R_{BE}) V_{BE}$$

$$(b) V_I = 10^4 \left( \frac{5 - V_0}{10^3} \right) / 100 + \left( 1 + \frac{10}{5} \right) 0.026 \ln \frac{5 - V_0}{10^3 \times 2 \times 10^{-12}}$$

$$V_I = \frac{5 - V_0}{10} + 0.078 \ln \frac{5 - V_0}{2 \times 10^{-12}}.$$

$$(c) V_I = \frac{5 - 2.5}{10} + 0.078 \ln \frac{5 - 2.5}{2 \times 10^{-12}} = 0.25 + 2.173 = 2.423 \text{ V}$$

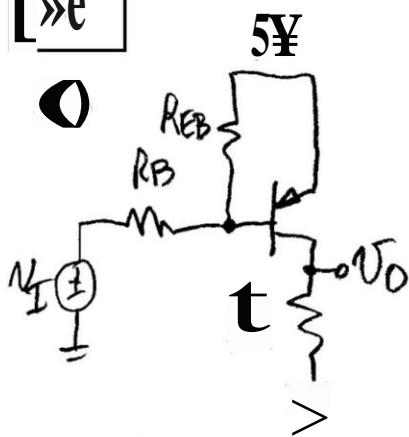
(Shifted to the right by about  $2V_{BE}$ 's).

$$(d) \frac{dV_I}{dV_T} = \frac{1}{10} \frac{dV_0}{dV_T} + 0.078 \frac{2 \times 10^{-12}}{5 - V_0} \left( -\frac{1}{2 \times 10^{-12}} \frac{dV_0}{dV_T} \right) \Rightarrow$$

$$1 = -\frac{a}{10} - 0.078 \frac{a}{5 - V_0} \Rightarrow a = -10 \frac{5 - V_0}{5.78 - V_0}.$$

@  $V_0 = 2.5 \text{ V}$ ,  $a = -7.62 \text{ V/V}$ . In the example,  $a = -9.06 \text{ V/V}$ . Reduced gain stems from the presence of  $R_{BE}$ , which forms an input voltage divider with  $R_B$ .

[>e]



$$V_I = 5 - V_{EB} - R_B (I_B + \frac{V_{EB}}{R_{EB}})$$

-5-6%-(\\$)es, VS... & 010?

Impose SS%-%-(%:  
+0 or -; (& es.

&) e-5-10 #; -3 roeo (@to"),  
=5-}o- 0.07 & n lc" «ca). p./oo»dials wrb Or:

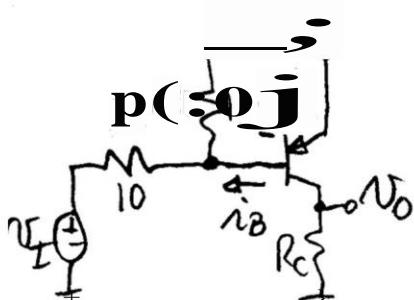
1= %2,-0bee "#|

' > ±##- £ d 1% ; n ss -'

too, -75%, gm= n g s g = -10.7 V/V

:S

(I, «A. «; -e, -We, -&e(@e'"§)



**-κ&ετ-(t@/s) Ζ**

=**s-lo"is-** 2es.

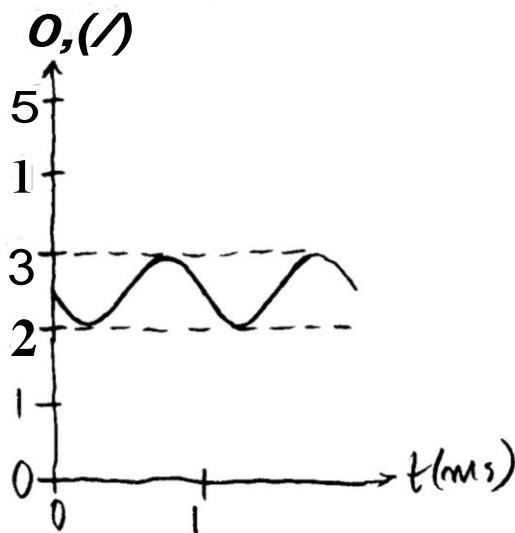
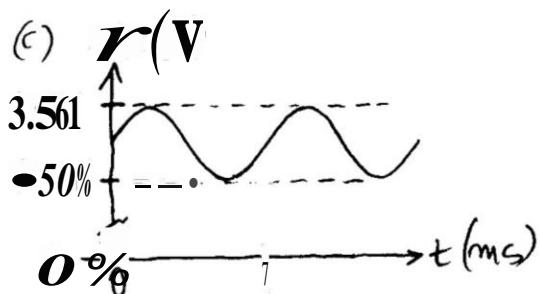
O, C-6' O -20L, -O/29  
25lc'

$\Rightarrow -5.5^{\circ} 00' 22''$  ova).

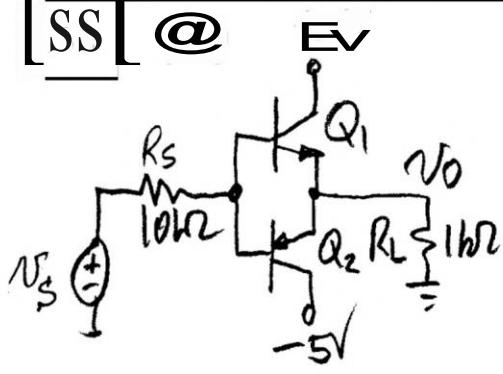
==5-,-00sh(to'a)=3s7 V

**2s-3-0052 (D) .0% V**

**a=(6-2) / -s0¢-3.567) =(@v) / (-%l») =-%.4 //**



[SS] @



VC? *i b i s, so owl-* {  
tu con **r o.** [,A,j.]

**O < O, O. % = O = Co.**

$\rightarrow 0. V \Rightarrow Q = E 0 \phi,$

$$0 < O < 5 - 0.2 = 4.8 V \quad O = r_-$$

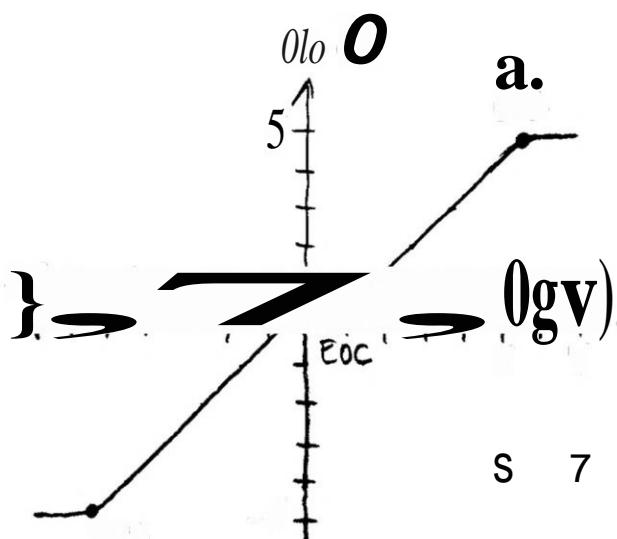
a.

**O = - V\_S**  $O = \epsilon 0\%, \gg l$

$$Z = 48 + 07 + R_L \lg f$$

$$- 55 + 0 \cdot \# f$$

$$= 5.88 V \rightarrow 4+++$$



S 7

$$\Rightarrow V_O = 5.55 / 0 \text{ ch}$$

e05 -S

$$(e) \% - 2.5 V = U_r \rightarrow 2.5 + 07 + 10^{\frac{gs}{1\%}} ) 7 \pm 345 /$$

[ ] 6

A	8	@	G	'(
L	L	Co	Co	kH
L	H	Co	Sk	L
H	L	St	G0	L

$$(b) \beta_{F(\min)} > \left( \frac{5 - 0.1}{1} \right) / \left( \frac{5 - 0.8}{10} \right) \approx 12$$



2.40

@6

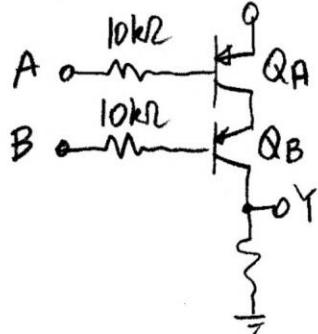
A	8	@	%	Y
L	U	Co	Co	HL
	H	C	Co	H
H	L-	Co	Go	H
H	11	%t	sad	L-

$$O - [74p1 / \underline{= \frac{0.8+0}{10}}] \cdot \% +$$

$$Z, [4_{0.1}^{0.1}, \cancel{+44} \cancel{\#} \checkmark]$$

2.41

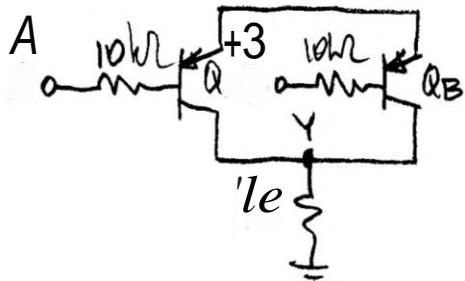
50



A	3	QR	--	Y
L	L	51	\$k	H
L	J	O	Go	L-
A	L	Co	Co	L
H	H	Co	Co	L

2.42

gV



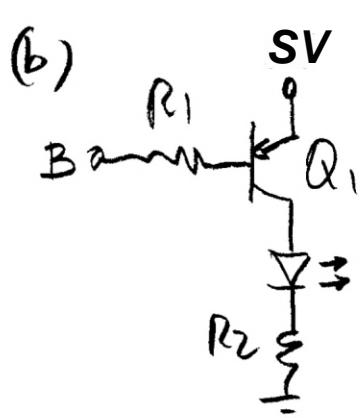
A	3	Q	S	Y
L	L	b	1	L
-	Sa1	O	H	
k	L	Co	5	H
H	H	Co	Co	L

" | (@) 0a- (5-15-0) - 03+»02 (ee 3309).

1) > (5-1.5-0.) / 0.33 - 103α

I (0») - 10✓50 - 020%auA.

& < G-08) / 0.20€ - 2on



3=1-0V>O-S t Z Eb 9m.

BH6/0-Co => LE ~ dank

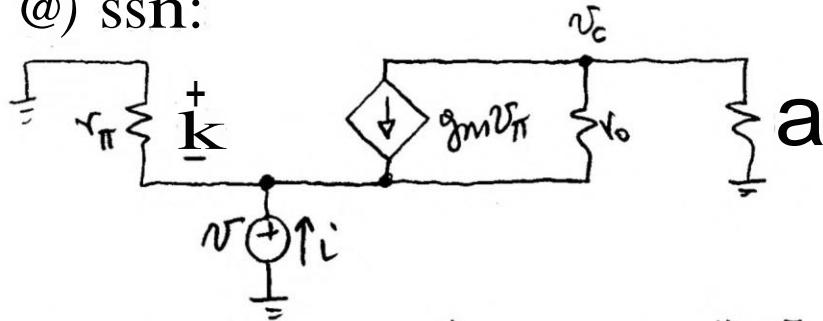
prwrg, 7.e Sam. parameters

no Z 6S4 part o

@-10Z , ll, 3309.

**U**

@) ssn:



KVL:  $V_{pi} = -V$ . KCL:  $i + \frac{V_{pi}}{r_{pi}} + g_m V_{pi} + \frac{V_c - V}{r_o} = 0$ , or

$$i - \frac{V}{r_{pi}} - g_m V + \frac{V_c - V}{r_o} = 0. \text{ Supernode: } i = \frac{V}{r_{pi}} + \frac{V_c}{R_c}, \text{ or}$$

$$V_c = R_c \left( i - \frac{V}{r_{pi}} \right). \text{ Eliminating } V_c \text{ gives}$$

$$i \left( 1 + \frac{R_c}{r_o} \right) = V \left( \frac{1}{r_{pi}} + g_m + \frac{1}{r_o} + \frac{R_c}{r_{pi}} \frac{1}{r_o} \right) = V \left( \frac{1}{r_e} + \frac{1}{r_o} + \frac{R_c}{r_{pi}} \frac{1}{r_o} \right)$$

$$R_e = \frac{V}{i} = r_e \frac{r_o + R_c}{r_o + r_e + (r_e/r_{pi}) R_c}. \text{ Considering that } r_e \ll r_o$$

$$\text{and } \frac{r_e}{r_{pi}} = \left( \frac{\beta_0}{\beta_0 + 1} \frac{1}{g_m} \right) / \left( \frac{\beta_0}{g_m} \right) = \frac{1}{\beta_0 + 1}, \text{ we get}$$

$$R_e \approx r_e \frac{r_o + R_c}{r_o + R_c / (\beta_0 + 1)} = r_e \frac{1 + R_c / r_o}{1 + R_c / [(\beta_0 + 1) r_o]}$$

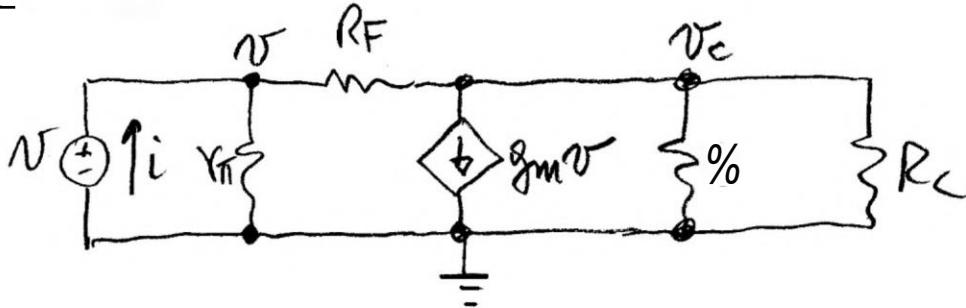
$$(b) r_e = \frac{100}{101} \times \frac{26}{1} \approx 26 \Omega, r_o = \frac{100}{1} = 100 k\Omega$$

$$R_e \approx 26 \frac{1 + 10/100}{1 + 10/[101 \times 100]} \approx 28 \Omega.$$

$$(c) R_e \rightarrow r_e = 26 \Omega.$$

$$(d) R_e \rightarrow r_e \frac{R_c / r_o}{R_c / [(\beta_0 + 1) r_o]} = r_e (\beta_0 + 1) = r_{pi} = 2.6 k\Omega.$$

[4] S



$$i = \frac{V}{R_\pi} + \frac{V - V_C}{R_F};$$

$$\frac{V - V_C}{R_F} = g_m V + \frac{V_C}{r_o // R_C} \Rightarrow V \left( \frac{1}{R_F} - g_m \right) = \frac{V_C}{R_F // R_C // r_o} \Rightarrow$$

$$V_C = \frac{R_F \times (R_C // r_o)}{R_F + (R_C // r_o)} \frac{1 - g_m R_F}{R_F} V = \frac{R_C // r_o}{R_F + (R_C // r_o)} (1 - g_m R_F) V;$$

$$\begin{aligned} i &= \frac{V}{R_\pi} + \frac{1}{R_F} \left[ 1 - \frac{R_C // r_o}{R_F + (R_C // r_o)} (1 - g_m R_F) \right] V \\ &= V \left[ \frac{1}{R_\pi} + \frac{1}{R_F} \frac{\cancel{R_F + (R_C // r_o)} - \cancel{(R_C // r_o)} + g_m R_F (R_C // r_o)}{R_F + (R_C // r_o)} \right] \\ &= V \left[ \frac{1}{R_\pi} + \frac{1 + g_m (R_C // r_o)}{R_F + (R_C // r_o)} \right] \end{aligned}$$

$$R_i = \frac{V}{i} = \left( \frac{1}{R_\pi} + \frac{1 + g_m (R_C // r_o)}{R_F + (R_C // r_o)} \right)^{-1} = R_\pi // \frac{R_F + (R_C // r_o)}{1 + g_m (R_C // r_o)}$$

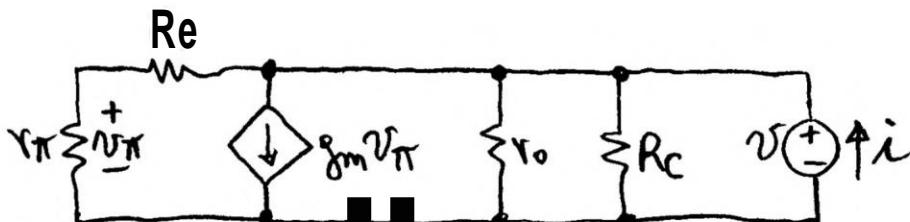
$$(b) R_\pi = 100 (26/1) = 2.6 \text{ k}\Omega, r_o = 100/1 = 100 \text{ k}\Omega, g_m = 1/(26\text{s})$$

$$R_i = 2.6 // \frac{10 + (1//100)}{1 + (1//100) 10^3 / 26} = 2.6 // 0.281 = 254 \Omega.$$

(c)  $R_F \rightarrow 0$  and  $R_C \rightarrow \infty \Rightarrow$  BJT is diode-connected,  
and  $R_i = R_\pi // \left[ \frac{r_o}{1 + g_m r_o} \right] \rightarrow R_\pi // \frac{1}{g_m} = r_e \cong 26 \Omega.$

(d)  $R_F \rightarrow \infty \Rightarrow R_i \rightarrow R_\pi // \infty = R_\pi.$

[246] @955:



C: - ~~#~~<sup>W</sup><sub>c</sub> + e. . : r- de.  
∴ { a<sup>+</sup> P - , f<sub>n</sub> - 3 - flr - ? <sub>n</sub> hr. W »

*i:-v* — Kr+fr *F* *i* . ?  
- he' R..5, *per* (5 @r±'r . t,  
*i:9#* . S // - / cl(e-~{i})

(f) 2ca, - 00 , @,- //8@u4!])5 in.

**@deO,ca)**  $\mathbb{K} = //f\!egte$  (T=ode).

@) W.1 tkc lase  $\tau \ll e$  •  $\langle \rangle$ , On  $\sigma \ll a\}$ ,  $> 0$ .

**h**a4hrs., (G.) Kelk ✓@c.

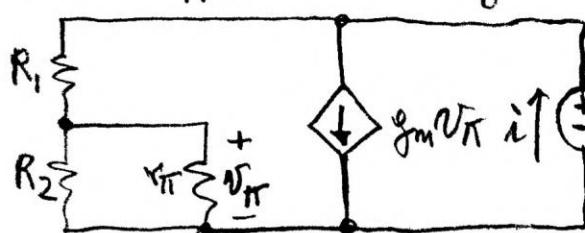
2.47

Apply test voltage  $v$ :

$$N_{\pi} = \frac{R_2/(r\pi)}{R_1 + (R_2/(r\pi))} N$$

$$i = g_m V_{IN} + \frac{V}{R_1 + (R_2 // r_{IN})}$$

$$= \frac{g_m (R_2 // r_{IN}) + 1}{R_1 + (R_2 // r_{IN})} V$$



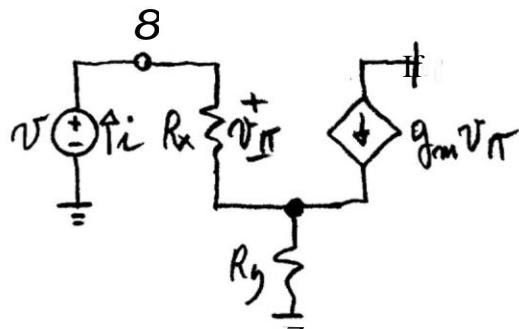
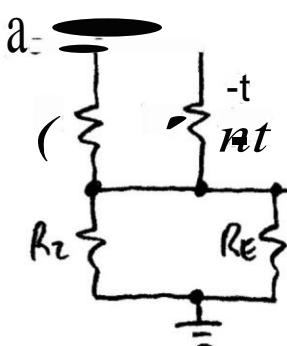
$$R = \frac{r}{i} = \frac{R_1 + (R_2 // r_N)}{1 + g_m (R_2 // r_N)} = \frac{[12 + (15//10)]10^3}{1 + (15//10)10^3/50} = \frac{18000}{121} = 149 \Omega.$$



12.43] @ 6 dim, R- (+a- Re- g 5.0)

K-@@LL[++(39)]

(b)



wt. ~~td~~ sold cbel  $\rightarrow$  9 tA cktks BAL.  
Tio,  $T_s$ , o ~~ask~~ to v%. t t kens@t,  
WWila «e Jet 1 Rd» ad R> @ Z. ply  
a tot  $t_a, 0$  SO., - gw ,  $C_1$  &  $V_U$ ,  
- " : ea «r- 'ti'. d, or- & c. eta » ch,  
Cf&d , el t1gythenado - 0eo

$K_V = \frac{dV}{dt} = +(+, 09)83.$

(@)  $W = 1/(260)$ ,  $+r = 2.61$ . Fo ca(m) «w. gt

$\& - (0+) 1(7\% + t_0) = 10.6$  k C + 2 · ). F  
0ox(b) augt ( - loV. = 20% , , - 10/105;  
 $R = 2.00 + (+ - ) 2s - 6\% \leftarrow \mathbf{86}$ . Th» i  
ma.A. hew. ta. (6)! keWimp >>  
noise tkew vjpd pa « da » » sale~ht, !

" | @ ye- ( / ) 1-6, ve ( / ) 1-V, « e - @ - h =  
1.60 l, wt 9, - o Ta, 2 = ( @ O / e 0 = 20 A.

The a « R, - l o l a - 0.2 m 4, As su wig ve 5(a) = 0.1 ,  
me la. ve - ( - 0.7 ) 53 / 0 ( - 5.3 ) / 0.2 - ( 8.5 @  
( we @ u ) al , - 53 / ( 0.2 + 0.02 ) - 24 kn.

(2) & - | If - 10.3 , Veg - 9 » 24 / 18 + 24 ) 5. N V  
7, lee S - V e o w ,  
$$(8/g + c)$$

$$Tc \text{ (on v » 0) } y - \frac{-5.8 - o}{103/100 + 1.5} = 1,7 A$$

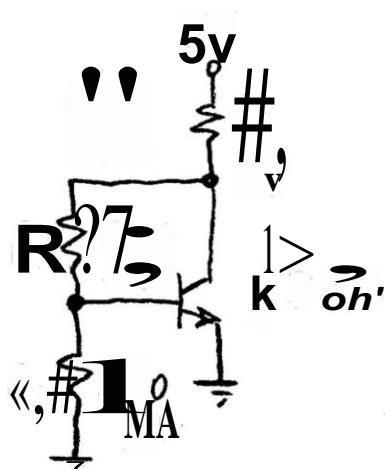
$$C \% a ) - \frac{-5.1 ( \text{on } 5 ) - 0.1}{( 0.5 - 5 ) [ s + 15 ( 0.5 ) ]} \approx 2.3 \% A$$

$$CO ) - \frac{-5.1 ( 1. g s ) - 0.1}{( 9.810 s ) / 5 + 15 ( C s )} = 1 / \sqrt{h}$$

( t 0.3 / - ± 5% eiadds a. Tc ).

**S**

@)  $Tg = 2 \gg 1020MA = IR_s$ .



$R_s - 07/0.02 - 35\text{kw} (re 3\%)$

$g = \frac{204}{0.02} - 375Z (e 33k)$

$\langle a - \frac{5.2}{2+0.0} \rangle 11 la (e Is#),$

$\langle e \rangle @ (S_B, b_e);$

$$Ve = 07 + 33(\% + 0.7/3\%) = 1.34 V + (30)2p.$$

$I_s = -(e92).51!Z = -$   ~~$I_s = 22 - 231\% = 242$~~   $\cancel{I_s = 273}$   ~~$I_s = 54, p$~~  Fe,  
IC;  $\frac{112}{2} j, \pi^3 = j, 0020 \frac{AL}{IC} 1.6\% l$

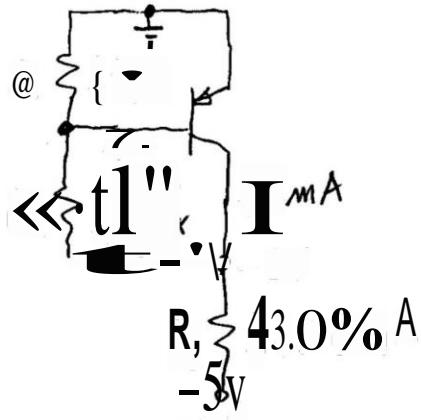
fr

A

1.1 «A, 2.(7au4. NetJaI! Mo2cu  $E = V$   
1 + 1c / » = 2.41, 1V, 10V, al reefs  
inolak rel 4 N.



[S] (e 1,-3/50 =704, , -9, =07/0=



m **S(v|8)**.  $I_k - I_{k1} N7$   
3P **μ**, (-f07-(3))\0.0%  
**3zK (Ia)**. — Te  
"112, ? + 0.0 G, '3, ob t#1A, Re~  
fa-(O\0-O#8n(we)a).

@ a. -o-8(%+4,) - « - (s+\$)=

**Ve=0-Ve** - 0.211+ **3ls.** @=R-I<sub>R</sub>, or

~~6-le. (e-e) - % - @275i - s-jg1\*~~

1c=5<sub>4</sub>- ova -3:7+-#f1 =Te/(n;)

**6-**)= ~~1/5~~ **2-auk**) Lc<sub>w</sub> - ~~27~~ -27%

mh} %or  $t \sim i - 23$  **Gorda'**  
ec(as)-z.an + n(@4/19)- .4 V,  
le(>>) 2.8 W Vac(8>) - 2.2 V.



---

[a] @)  $r = re - (3-05)l_+ = 1.0 \gg$

(9)  $V_e = T \exp(0he/t_c) - 10 \exp(0) - 1.080 \% A$

@)  $T_c = 1a @ p(25/26) - 1\% 1 K$

(@)  $V_e = 0o - 2lo = 6806V,$

rag  $\# 0+8)/4 = (2/43) \gg;$

$re = \# , op(-vs0) - 0.\% ah$

(@) News often & T(@)  $> 1(02), \gg A$  that  
7/-7@)- 4 #, - znc.

---

2s ] a-(s-00% - 10% +

(@) 1a=0||aA - (wA\o)y 22. 2tule, 4hobo,

ezoo-60 (818700- 24al > DY, = 2le \gg V;

@=4%/a- 2\0.4=60 5-

(') 5-o+18-18 \# , @- 1&/0.0s= 1560-

(@) AV%- (%av) - (so\z3)= 5i. \sigma, @- 546/0.12z

=N7 -

2.54

$$(a) V_{BE1} = (26 \text{ mV}) \ln \frac{(6 - 0.7)/10^4}{2 \times 10^{-15}} \approx 684 \text{ mV}$$

$$V_{BE2} = 0.026 \ln \frac{0.684 - V_{BE2}}{10^3 \times 2 \times 10^{-15}} ; \text{ start out with } V_{BE2} = 0.6 \text{ V.}$$

$$V_{BE2} = 0.026 \ln \frac{0.684 - 0.6}{2 \times 10^{-12}} = 0.636 \text{ V}$$

$$V_{BE2} = 0.026 \ln \frac{0.684 - 0.636}{2 \times 10^{-12}} = 0.620 \text{ V}$$

Iterate further, and end with  $V_{BE2} = 626 \text{ mV}$ .

$$I_{C2} = (0.684 - 0.626)/10^3 \approx 58 \mu\text{A.}$$

(c) With  $V_{CC} = 6 \text{ V}$ ,  $I_{C1} = (6 - 0.684)/10 = 0.5316$ ;

$(1/2)I_{C1} = 0.5316/2 = 0.2658$ ; Rule of Thumb:

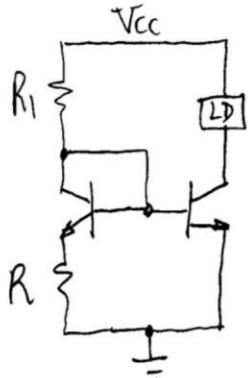
$V_{BE1} = 684 - 18 = 0.666 \text{ V}$ ;  $V_{CC} = 0.666 + 10 \times 0.2658 = 3.324 \text{ V}$ . Reiterate as before, and find

$$V_{BE2} = 0.026 \ln \frac{0.666 - V_{BE2}}{2 \times 10^{-12}} \Rightarrow V_{BE2} = 620 \text{ mV} \Rightarrow$$

$I_{C2} = (0.666 - 0.620)/10^3 = 46 \mu\text{A}$ . While  $I_{C1}$  has dropped to  $\frac{1}{2}$  its initial value,  $I_{C2}$  has dropped from  $58 \mu\text{A}$  to  $46 \mu\text{A}$ . Not  $1/2$ , as  $I_{C2}$  is not linearly proportional to  $I_{C1}$ .

[S]

$$(1, -) \sim = V_{e=}(00aV@ = l \gg A)$$



$$C_y - 0.5aL > V_{ee} = 70 - 18 - 68 \geq V$$

$$I_{ca} = 0\% = V_{e2} = 70 + I_R = 7/\&n$$

$$\therefore \& = @8-682bs- '72 ,$$

$$4-(@.O8)/a.s- 8.564 MR.$$

(8c)  $I_{uA} \Rightarrow E = 10 \gg I, V_a 721 - 72 \% iV.$

$he2 = T_0 O2 - 772 \% V - (700r 4.18) Vt 1 '' >$

$I_{(auk. Ta, S)} I_{uA}$  ve, hon da«led once,  $T_{ha}$

le«l-al Jato»!

[I]

$$@) \sim -(2- = 9/ = z. \leftarrow 2co).$$

$$\&z- (56-07)/2 - 2 - 5 \leftarrow e 2.4 .$$

$$\% - 2/6 - / (13), z = 00x1 = 13k0; r\% > 37\% 2.$$

$$K = - [+] . (@a//o) = 31/ + (@cl06/ \uparrow 1 2.5 Mn.$$

(b) **A owes**  $2n$  V doeneao  $V_c$  as  $\%wo$ , *deedens*

$7\%$ , The 2do ~~X~~ ie SUE tat  $41\% / 4 = \frac{1}{5 \times 10}$  -  $0.0A/V$ . At **CUE** vs  $JAVe] \gg cveow \rightarrow t$

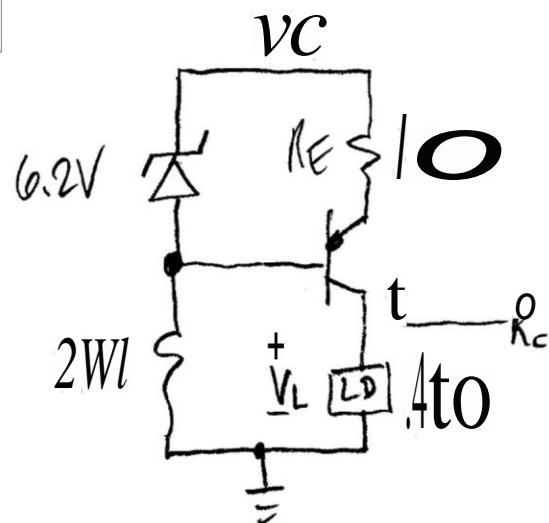
$V_a awl V_e$ , «cc#kip To

$s = ;te, l''el- \ddot{A} - le. l'' \ddot{A} , s - luveal.$

$BL\% - AN, A = \frac{|Ae|}{1 \times 10^3} \rightarrow \frac{|Ae|}{5 \times 10^6} - (ye09)r''] Ad$

:#et-3] +.

[S]



kuoiiiceee 2 « 1 dovwole otoolovuos0To.

$\frac{I_o}{E}$ ,  $R_c$  de

$\frac{0.55}{0.55}, \frac{0.55}{0.55} \times 100\% = 100\%$

$I_e = 12.5 \text{ mA}$  - 80% 4 N.

ttow<code v veoi.csts V annel 0 V

$4 - \frac{\% \# \%}{\# \%} a_{Ac} - 4\% a = \# \cdot \# \%$

$Z_{AN<C} A_{O2} 4^{Ne} [fig 7] 125M \#$

$410 - A - Aa(d'a'as) - 1\%$   
 $\{57 = \frac{1}{9}\% = 1\%$



[ass] @ ) 1% 7 74 ~~to~~ ~~O~~ ~~I~~ S. = 73, I + 1.07% A,

Ng - 3 713210? = 0.41V

V<sub>e</sub> - V<sub>+</sub> Vee[») = 0.241 + 0.7 = 0.41 V

= -10 + 7.07 - -82 V.

M<sub>r</sub> =  $\frac{1.01}{2H}$  =  $\frac{1}{27n}$  )  $\frac{7}{2} \frac{44}{5} O$  o- 144 z kt.

$\frac{K_{\text{v}_0}}{g} = \frac{3}{3+3.2} \frac{3.55}{(235)} \frac{2}{60} \frac{3}{12} \frac{47}{Zn^2} = 4.20 W$

e)  $-V_+ = 0 + 5, (O_b$

= 0 - V + (k.57 ml) coot;

-W + 0. = -u z v - 121 (5av) q z;

v = -4.82 V + (0.005 V) 0 » (e - 180);

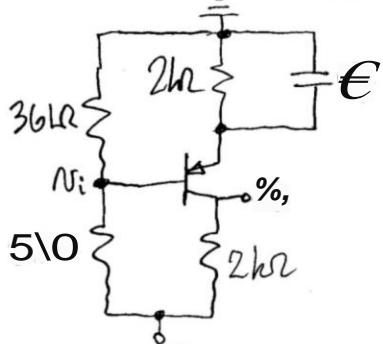
E = 0 + (.60 sv) C (t - 180°);

= o, ZV + 0,



**S»**

$$@ V\% - \frac{2e}{3\%+51} = -3.12V$$



$$S - \% / 51 = 2n$$

$$Ta - C P 12-0 - ZIK15T2 - 1. u, A$$

$$\theta, \sim > 208k - 310$$

$$-aw @v - \% // S // 28-25|3, R = 2/13-2610,$$

$$eh - \% | 0 = - 2.9 \times 0.01855 - 133 L.$$

$$e) \rightarrow - e Re/(e.+)- 18.5 + 21g0/1915 1600.$$

$$\rightarrow 1/(<60x10^3) 2 J. le Cc=10, F.$$

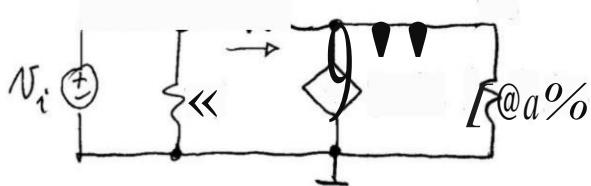
$$[z@] ;V, +, a]. - t0- 1c+681z/2l+07 >$$

$$e = 2.08\% n \quad IC = 2.07\% A \quad I = I/(2.0\% n), Yr =$$

$$1.5n, 1 \cdot z 48 M, R// = 3.48 3.\% 2$$

$$\langle - \rangle_{Rr+(@a)} - , e 8+3.1 - z 2n \\ "l j g(@d.) " + 3. @/. 6$$

$$= oh[: \{ ]e \ll ft. #4 \cdot \ll sr$$



$$\frac{Vi}{ne} e - \pm$$

@%

**U**

-o\*\*\*

@el.

$$e(\#e - \cdot (\# \% > \# . n)$$

$$\# . : - \% - \# k)(e el \& dee) = -(kn . ka)(\# Z / ) \cdot n \#$$

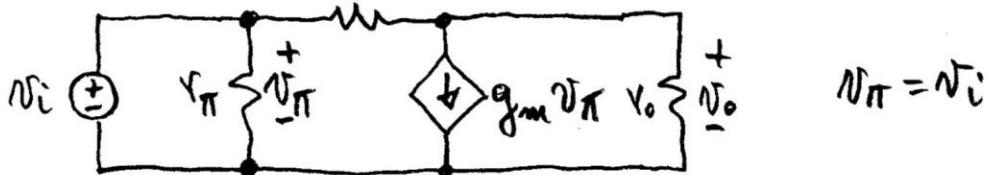


[26] @)  $I_C = I_A$ ;  $I > dT_o \gg A$ ,

$Z = Te/((@+)) - (1/t_0) \approx F$ ;  $V_e = V_{e0} + Rr T_s - 0.7 + loo/0l$   
 $\approx 1 - V$ ,  $\approx . - VO91 = lot Ml$ ,  $3\% - 0.9/2\% = 1/(2.35)$ .

5M:

[F]



$$N_\pi = N_i$$

CL:  $\frac{@-ve}{@E} \% \approx \frac{1}{R_s} = \frac{O(4.-1)}{R_s} / K$ ,  $9e\% T_T$ ,

$\% . - - S \ll (t)(t, 'e,) - - 2 \cdot e o 0 a) w (- \frac{1}{2})$

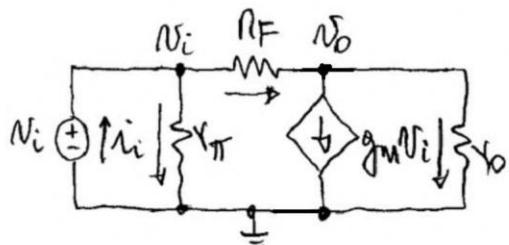
$= -1/3 \text{ V}$ .

(b)  $\rightarrow$  dodMe, e os / ! Z t.else » to 50. SER,

no « 6, kin W t ht l: - \$ (Re// - ), s  
 $\% = - [\$,- (o Z S) y w ? - - 2 s 5 5$  W. bee 4 -

huace, Re, w!cd was unc ap, Te A abv,  
 $\# } \ll pa\&- \% on t t h e l i - \} 4 S, » e W$   
 $o g l e i c n w a e o$ .

2.62

(a)  $I_C = 1 \text{ mA} \Rightarrow g_m = 1/(26 \Omega)$ ,  $r_{\pi} = 2.6 \text{ k}\Omega$ ,  $r_o = 100 \text{ k}\Omega$ .

$$\text{KCL: } i_i = \frac{V_i - V_o}{r_{\pi}} + \frac{V_i - V_o}{R_F} = \frac{V_i}{r_{\pi}/R_F} - \frac{V_o}{R_F}$$

$$\text{KCL: } \frac{V_i - V_o}{R_F} = g_m V_i + \frac{V_o}{r_o} \Rightarrow$$

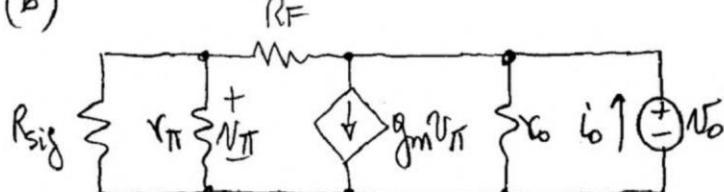
$$\frac{1 - g_m R_F}{R_F} V_i = \frac{V_o}{R_F / r_o} \Rightarrow$$

$$V_o = \frac{1 - g_m R_F}{R_F} \frac{R_F r_o}{R_F + r_o} V_i \Rightarrow V_i = \frac{1 - g_m R_F}{1 + R_F / r_o} V_i \Rightarrow i_i = \frac{V_i}{r_{\pi}/R_F} - \frac{1 - g_m R_F}{R_F(1 + R_F / r_o)} V_i$$

$$R_i = \frac{V_i}{i_i} = r_{\pi}/R_F \parallel \frac{R_F(1 + R_F / r_o)}{g_m R_F - 1} = 2.6 \parallel 100 \parallel \frac{100(1 + 100/100)}{100/0.026 - 1} \approx 52 \Omega.$$

If  $R_L = 100 \Omega$ , replace  $r_o$  with  $r_o/R_L = 100/100 = 50 \Omega$ . Then,  $R_i = 2.6 \parallel 100 \parallel \frac{100(1 + 100/50)}{100/0.026 - 1} \approx 76 \Omega$ .  $R_i$  is dominated by the third term, roughly representing  $R_F$  divided by the gain  $|V_o/V_i|$  (Miller effect). Loading the amplifier reduces the gain and thus increases  $R_i$ .

(b)



$$i_o = \frac{V_o}{r_o} + \frac{V_o}{R_F + (R_{sig}/r_{\pi})} + g_m \frac{R_{sig}/r_{\pi}}{R_F + (R_{sig}/r_{\pi})} V_o = V_o \left[ \frac{1}{r_o} + \frac{1 + g_m (R_{sig}/r_{\pi})}{R_F + (R_{sig}/r_{\pi})} \right]$$

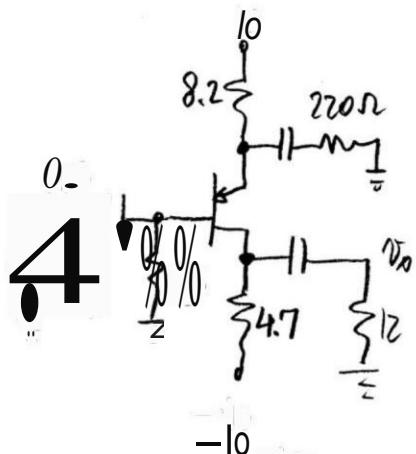
$$R_o = \frac{V_o}{i_o} = r_o \parallel \frac{R_F + (R_{sig}/r_{\pi})}{1 + g_m (R_{sig}/r_{\pi})} \cdot R_o(R_{sig}=0) = r_o/R_F = 50 \Omega.$$

$$R_o(R_{sig}=1 \text{ k}\Omega) = 100 \parallel \frac{100 + 1/2.6}{1 + (1/2.6)/0.026} \approx 3.4 \text{ k}\Omega$$

With  $R_{sig} \neq 0$ ,  $V_{\pi} \neq 0$  and  $g_m V_{\pi} \neq 0$ , so  $i_o$  increases, reducing  $R_o$ . In the limit  $R_{sig} \rightarrow \infty$ , we get  $R_o \rightarrow 1 \Omega$ .

2.63

[ , Au]: 2. «el&gt;



$$\text{Te- } \frac{10-97}{33+2.8.2} \& 724 /$$

$$C-253572 = 40\% A$$

$$7m- \frac{10}{17} 75.7$$

$$\text{Gr- } 2523, 8218 k_$$

$$-(al/n=3/11 + (las6)(3.20))]- 1s.9 \ln$$

$$Kz802kl$$

$$\frac{E_{158}}{\text{@ } 7H3} [ \frac{L^{3.8}}{1+(1/527)} g^7, ) \frac{12}{g^7} \\ --n^2/V$$

[264]  $(@) \approx 105 \frac{-10.07}{100+2\%} g^7 \mu, \quad 0 = 07.2\% =$

$$1/(72), \quad -'257 + .6 \text{ kn.}$$

$$\langle ; - (0.01 R_S - 10/[4.6 + 1\% (s/0.)]) - 4w, t = 0.1 \rangle$$

$$N_i - \frac{E}{k, (v_s - v) @ ?} = \frac{-10.07}{10.1 S} F74 /.$$

$$6) \quad \text{oa} + \text{isa} // \langle, - oo + [sol/31 + \$, \rangle] \\ = 88 - C > \sqrt{(.a & 88702) - 1} \& F.$$

Ve 2OF.

e tie, th<<> .hp»t% #:- #,t;--0<< V/v.

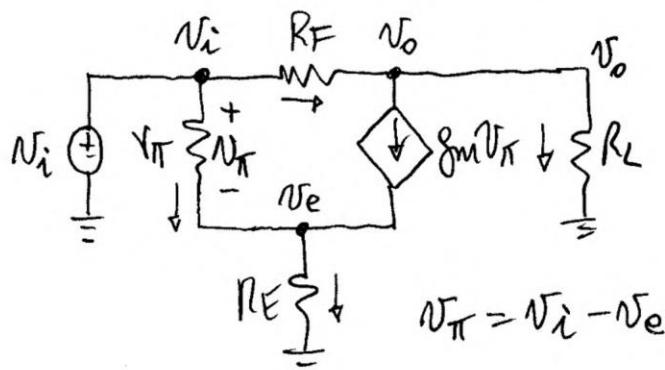
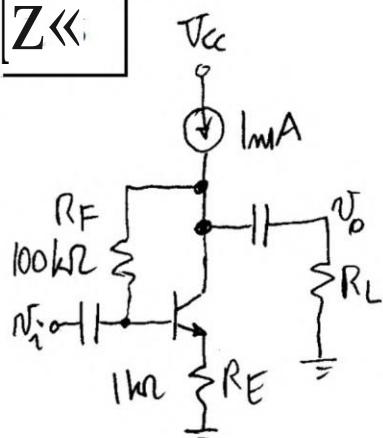
vs] @)Mee - .01s- lo, 5- [75%+15] 1=3%.  
Tc-0o ~~201~~<sub>0+101x22</sub>, oal, w- m, a) - 200.

he-t/fat +o@aj:- kn, • 7 27 In  
A/- ht toon? 7 =- 1. //

', tell@vu. "5:1- son  
> i(c? «zQ)- «, 5F ve Cs=19F.  
65-, kt- -, 4 the-!



$Z \ll$



$$I_C = \alpha I_E = \frac{150}{151} I \approx 1 \text{ mA}, \quad g_m = \frac{1}{26.2 \text{ k}\Omega}, \quad r_\pi = 39.3 \text{ k}\Omega.$$

$$\text{kCL at } V_{re}: \frac{V_i - V_{re}}{r_\pi} + g_m (N_i - V_{re}) = \frac{V_{re}}{R_E} \Rightarrow V_{re} = \frac{1}{1 + r_{re}/R_E} N_i$$

$$\text{kCL at } N_o: \frac{N_i - N_o}{R_F} = g_m (N_i - V_{re}) + \frac{V_o}{R_L} \Rightarrow$$

$$N_i \left( \frac{1}{R_F} - g_m + \frac{g_m}{1 + r_{re}/R_E} \right) = N_o \left( \frac{1}{R_F} + \frac{1}{R_L} \right) = \frac{N_o}{R_F \parallel R_L}$$

$$\frac{N_o}{N_i} = \frac{R_F R_L}{R_F + R_L} \frac{1}{R_F} \left[ 1 - g_m R_F \left( 1 - \frac{1}{1 + r_{re}/R_E} \right) \right] = \frac{R_L}{R_F + R_L} \left[ 1 - g_m R_F \frac{r_{re}}{R_E + r_{re}} \right]$$

But,  $g_m r_{re} \approx 1$ , so

$$\frac{N_o}{N_i} = \frac{1}{1 + R_F/R_L} \left( 1 - \frac{R_F}{R_E + r_{re}} \right) = \frac{1}{1 + 100/100} \left( 1 - \frac{100}{1 + 0.026} \right) \approx -48 \text{ V/V.}$$

For  $R_E \gg r_{re}$ , we can approximate

$$\frac{N_o}{N_i} \rightarrow \left( 1 - \frac{R_F}{R_E} \right) \frac{1}{1 + R_F/R_L} = -\frac{99}{2} \text{ V/V.}$$

2.67

$$(a) R_i = r_{\pi 1} + (\beta_{o1} + 1) (R_E // r_{e2}) \cong r_{\pi 1} + (\beta_{o1} + 1) r_e = 2r_{\pi 1};$$

$$R_c = r_{o1} [1 + g_m (r_{\pi 1} // R_E // r_{e2})] \cong r_{o1} [1 + g_m r_e] \cong 2r_o;$$

$$R_o = R_C // R_c \cong R_c; \frac{V_o}{V_{sig}} = -\frac{g_m R_o}{1 + g_m (R_E // r_{e2})} \cong -\frac{g_m R_o}{2}.$$

$$(b) I_{C1} \cong I_{E1} = \frac{1}{2} \frac{12 - 0.7}{7.5} \cong 0.75 \text{ mA}$$

$$g_m = \frac{0.75}{26} = \frac{1}{34.7 \text{ m}\Omega}, r_o = \frac{100}{0.75} = 133 \text{ m}\Omega; r_{\pi} = 200 \times 34.7 = 6.9 \text{ k}\Omega$$

$$R_i \cong 2r_{\pi 1} = 13.8 \text{ k}\Omega; R_c \cong 2 \times 133 = 267 \text{ m}\Omega; R_o = R_c // R_C = 267 // 10 = 9.64 \text{ k}\Omega; \frac{V_o}{V_{sig}} = -\frac{1}{2} \frac{9640}{34.7} \cong -140 \text{ V/V.}$$

$$268] \frac{R_o}{OIS} = \frac{R + \pi}{1 + \frac{(3+0)}{(3+0) (1K_0)}} \approx \frac{1}{1 + \frac{R_{sig} + \gamma\pi}{(\beta_0 + 1) R_L}}$$

Woe n« Oe @ \$ >> K.

$$0.853 = \frac{L}{L - \frac{DK}{(1+0)700}} = \frac{1}{1 + e/100} \quad \varphi = 51.752$$

>  $I_s / \% = 26.5' 7.0.5 \mu h.$

$$0.1!& - \cancel{,kt} - \cancel{-10'4}, fe - 4\cancel{\phi} 33.2, 51 \\ \cancel{-(@)}_L \quad (\% +) \% \quad 00 \quad + \cancel{H} \quad 30$$

7C-150, Y «= 1551.7 = 775 -

#ij, ass'h a- 08W VW.  
T - 15ix.zoo

~~z@le kt, (w) = - .V, k\_w - c / = 2.8~~

~~n 1-0 17 26  
7.0 + a 3 J J J 720,~~

~~05x13.2 - lb5nl, w - 807.7 = lo - WI = w~~

~~- 8all [ee { + ) ee 1, k. } ./ fus+a ( la ) = K  
t-v ftñ" - ] #Morr # - aoae~~

$$\begin{aligned} \frac{23.4}{1+23.4} V_{sig} &= 0.959 \\ = 0.959 V_{sig} & \end{aligned}$$

$$\frac{V_o}{V_{sig}} = 0.959 \frac{1}{1 + \frac{1.65 + 0.959}{126 \times 1.166}} = 0.942 \text{ V/V.}$$

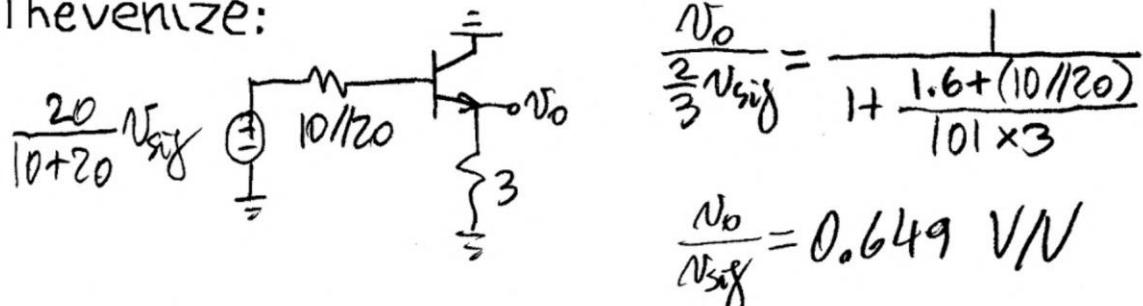
2.70

$$(a) I_C = 100 \frac{6 - 0.7}{20 + 101 \times 3} = 1.64 \text{ mA}, r_e = 15.7 \Omega,$$

$$r_\pi \approx 1.6 \text{ k}\Omega. R_i = 20 // (1.6 + 101 \times 3) \approx 19 \text{ k}\Omega$$

$$R_o = 3,000 // [15.7 + (10,000 // 20,000) / 101] \approx 80 \Omega.$$

Thévenize:



$$\frac{V_0}{\frac{2}{3}V_{sig}} = \frac{1}{1 + \frac{1.6 + (10/120)}{101 \times 3}}$$

$$\frac{V_0}{V_{sig}} = 0.649 \text{ V/V}$$

(b) With  $C_2$  in place, the upper  $10\text{-k}\Omega$  resistance is placed in parallel with  $r_\pi$ , giving  $r_{\pi(eq)} = 10 // 1.6 \approx 1.4 \text{ k}\Omega$ ; the lower  $10\text{-k}\Omega$  resistance is placed in parallel with  $R_E$ , giving  $R_{E(eq)} = 10 // 3 = 2.3 \text{ k}\Omega$ . We now have

$$R_i = r_{\pi(eq)} + (\beta_0 + 1)R_{E(eq)} = 1.4 + 101 \times 2.3 = 234 \text{ k}\Omega$$

$$R_o = R_{E(eq)} // \left( r_e + \frac{R_{sig}}{\beta_0 + 1} \right) = 2,300 // \left( 15.7 + \frac{10,000}{101} \right) = 110 \Omega$$

$$\frac{V_0}{V_{sig}} = \frac{1}{1 + \frac{r_{\pi(eq)} + R_{sig}}{(\beta_0 + 1)R_{E(eq)}}} = \frac{1}{1 + \frac{1.4 + 10}{101 \times 2.3}} = 0.953 \text{ V.}$$

Bootstrapping increases  $R_i$  significantly, thus reducing input loading and making gain closer to unity.

$$\begin{aligned}
 & [2n]_{Jr, -(s-05)/4} - \cdot \} mA, 2\% n = / \% n; \\
 & , = 15/16 k9; - 10 = 3 \cdot w2 \\
 & \therefore \underline{I_0} \quad n - \underline{\sqrt{75}} \quad (0s) a I \\
 & e = (%.8 \gg V) O, -0, e I c = e / \\
 & Ce + (@//.) \underline{0,020} \underline{(4,75)}
 \end{aligned}$$

(sad € } ) -.-[- @e/a

«,5 9a[11@ 300✓1 )✓.] = 6 mr-

# Fl 1a – \$-ta;

$e = Ye = 0.8(2/1.1) - 22.80$

$$m = Yz - 100(26/1.13) = 2.3 \bar{U}$$

$$8 = \text{tr} + (0a+)((el/Ra), \quad (=z+(pa+)(\sqrt{ht},))$$

& - & eI / Re, «e - g £ gyW  
[ol + ]

*Kt 23+10\ (10//O)- ('7% ML*

$\text{NK} = 2.3 + \sqrt{0.10 / 70}$  (1mC)

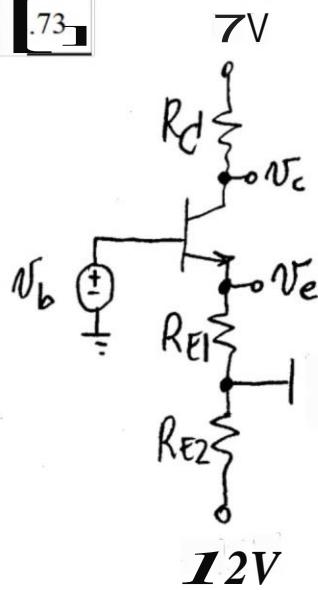
& -22s + "4;  $\nu n, 0.$  - //2z0352.

*O* *V<sub>0</sub>* *e<sub>v</sub>* *e*, *RuR<sup>c</sup>* *fRe* *2000* *le0oo*  
*Oe* *s<sup>r</sup>* *s*, *+R<sup>c</sup>* *er+fe1* *23+20¢e* *23+Ow00*

*O.4%5 Vly.*



[.73]



WW.  $I = 1A$ ,  $V = \text{?}$  V.

$$= R = GM (\text{ee } 4.2M, 5\%)$$

We kootit cefo  $\approx 4$  VV,  
to t a U eL, z-1 4V

$$Z = \frac{1}{f} \cdot \omega Lc \text{ mA},$$

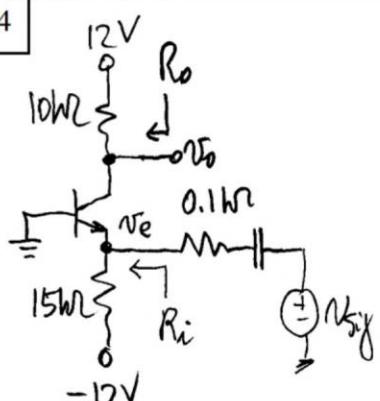
$$\text{nod. } e \cdot f - (r - 0) \text{ A},$$

$$Ke = 11.3\% \cdot 2 = 5.1 \Omega, 5\%.$$

8- eL // (et,) - s. // (6a + 000) - 2. & -

$$C > \frac{1}{2 \pi f R} = \frac{1}{2 \pi \cdot 10^3 \cdot 10} \text{ F} = 5 \mu\text{F.}$$

[2.74]



$$I_C \approx DE = \frac{12 - 0.7}{15} = 0.753 \text{ mA}$$

$$r_e = \frac{26}{0.753} \approx 35 \Omega, R_o \approx 10k\Omega.$$

$$R_i = 35 // (15k\Omega) \approx 35 \Omega.$$

$$V_e = \frac{0.035}{0.035 + 0.1} V_{sig} = 0.26 V_{sig}.$$

$$V_o = g_m V_e R_o = \frac{1}{35} (0.26 V_{sig}) 10,000 = 74 V_{sig}, \text{ so } V_o / V_{sig} = 74 \text{ V/V.}$$

[r] p, -, t- . SW (we . W;  
~~ek~~ = 10. R = 2.7 - 2.5 (we 2.4).

$$[9] = \frac{R_1}{x+@F5} - \frac{2400}{r+@cc7@} = \frac{I_C}{2H00} / p - 227 >$$

cha, k: ± O = 28(n 2402).

2.76

$$(a) R_i = R_1 // R_{e1}, R_{e1} = r_{e1} + \frac{r_{e2} // R_2}{\beta_{e1} + 1} \approx r_{e1};$$

$$r_{e1} = \frac{V_T}{I_{C1}} \approx \frac{26}{10/10} = 26 \Omega; R_i = 10,000 // 26 \approx 26 \Omega.$$

$$R_o \approx r_{o1} \left[ 1 + g_m \left( R_{sig} // R_1 // r_{\pi 1} \right) \right] = \frac{80}{1} \left[ 1 + \frac{1//10 // (150 \times 0.026)}{0.026} \right]$$

$$\approx 2.35 M\Omega. N_i = \frac{R_i}{R_{sig} + R_i} N_{sig} = \frac{26}{1000 + 26} N_{sig} = \frac{N_{sig}}{39.5}.$$

$$i_o = g_m N_i = \frac{1}{26} \frac{N_{sig}}{39.5} = \frac{N_{sig}}{1026 \Omega}.$$

$$(b) N_o = (R_L // R_o) i_o \approx R_L i_o = \frac{5000}{1026} N_{sig} \Rightarrow \frac{N_o}{N_{sig}} = 4.87 V/V.$$

(c) As long as  $R_{sig} \gg R_i$  and  $R_L \ll R_o$ , we have

$$N_o = R_L i_o = R_L N_i \approx R_L (N_{sig} / R_{sig}) \Rightarrow N_o / N_{sig} \approx R_L / R_{sig} = 5 V/V.$$