EE 321

Fall 2002

Homework #7

Solutions

4.5

Device	i_C (mA)	i_B (mA)	i_E (mA)	α	β
a	10.0	[0.10]	10.1	[0.99]	100
b	[1.10]	0.02	1.12	[0.982]	[55]
c	0.63	[0.01]	[0.64]	0.984	63
d	98.0	[1.0]	99.0	0.990	98
e	[0.010]	0.001	0.011	[0.909]	10
f	10.0	0.2	10.1	[X]	100
g	10.1	0.1	10.0	0.99	[X]
h	0.990	0.010	[1.00]	[0.99]	99
i	[2.90]	0.015	[2.91]	0.995	193

(a) $i_C = \alpha i_E \Rightarrow \alpha = i_C / i_E = 0.99$ $\alpha = \frac{\beta}{\beta+1} = 0.99$ ✓

$i_C = \beta i_B \Rightarrow i_B = i_C/\beta = 0.10\ mA$

(b) $i_B = (1-\alpha) i_E \Rightarrow \alpha = 1 - \frac{i_B}{i_E} = 0.982$

$i_C = \alpha i_E = 1.10$ $i_C = \beta i_B \Rightarrow \beta = i_C/i_B = 55$

(c) $\alpha = \frac{\beta}{\beta+1} = 0.984$ ✓ $i_C = \beta i_B \Rightarrow i_B = i_C/\beta = 0.01$

$i_C = \alpha i_E \Rightarrow i_E = i_C/\alpha = 0.64$

(d) $\alpha = \frac{\beta}{\beta+1} = 0.990$ ✓ $\alpha = \frac{i_C}{i_E} = 0.990$ ✓

$i_B = i_C/\beta = 1.0$

(e) $\beta = \frac{i_E}{i_B} = 1 : = 10$ ✓

$\alpha = \frac{\beta}{\beta+1} = 0.909$ $i_C = \alpha i_E =$

(f) $i_c = \beta i_B = 20.0$ Inconsistent

(g) $i_c = \alpha i_E = 9.9$ Inconsistent

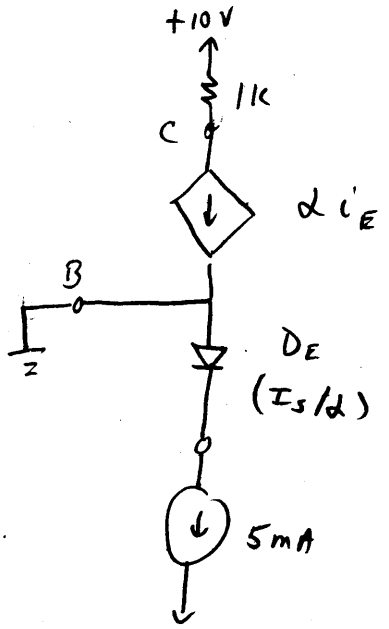
(h) $\beta = i_c/i_B = 99$ ✓ $\alpha = \frac{\beta}{\beta+1} = 0.99$

$i_E = (\beta+1) i_B = 1.00$

(i) $\alpha = \frac{\beta}{\beta+1} = 0.995$ ✓ $i_c = \beta i_B = 2.90$

$i_E = (\beta+1) i_B = 2.91$

4.10



$\beta = 100$

$I_S = 10^{-14}$ A

$i_E = 5$ mA $\quad i_c = \alpha i_E = \frac{\beta}{\beta+1} i_E = 4.95$ mA

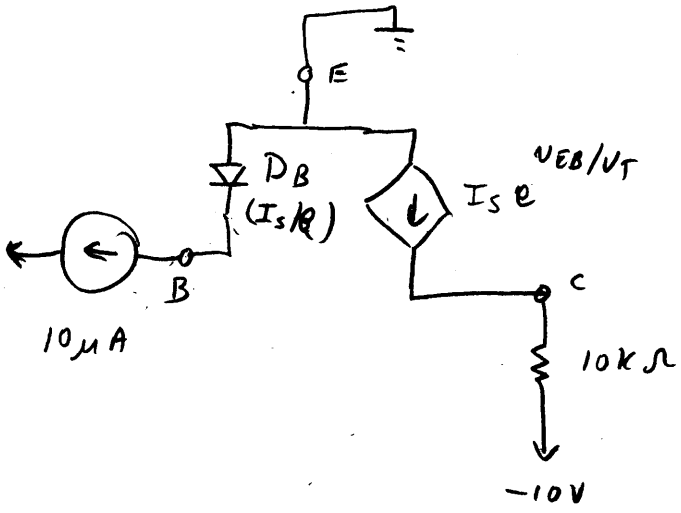
$i_E = (I_S/\alpha)\, e^{\frac{v_{BE}}{V_T}} \Rightarrow v_{BE} = V_T \ln \frac{\alpha i_E}{I_S} = 0.673$ V

$v_E = v_B - v_{BE} = 0\text{V} - 0.673\text{V} = -0.673\text{V}$

$v_c = V_{cc} - i_c R_c = 10\text{V} - (4.95\text{ mA})(1\text{k}) = 5.05\text{V}$

$i_B = i_c/\beta = 50.1\ \mu\text{A}$

4.15



$\beta = 40$

$I_S = 10^{-13} A$

$i_c = \beta i_B = (40)(10\mu A) = 0.40\ mA$

$i_c = I_S e^{v_{EB}/V_T} \Rightarrow v_{EB} = V_T \ln \frac{i_c}{I_S} = 0.553V$

$v_B = v_E - v_{EB} = 0 - 0.553V = -0.553V$

$v_C = -10V + i_c R_c = -10V + (0.40mA)(10k\Omega) = -6V$

$i_E = (\beta+1) i_B = (41)(10\mu A) = 0.41\ mA$

4.16

$i_c = I_S e^{v_{EB}/V_T} \Rightarrow I_S = i_c e^{-v_{EB}/V_T} = 1.27 \times 10^{-14}$

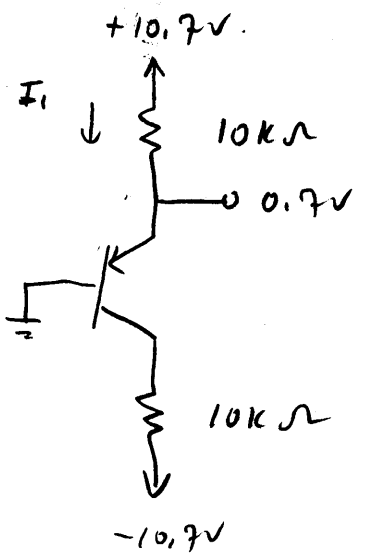
$v_{EB} = V_T \ln i_c/I_S$

For $i_c = 10\ mA$: $v_{EB} = 0.684\ V$

For $i_c = 5A$: $v_{EB} = 0.840\ V$

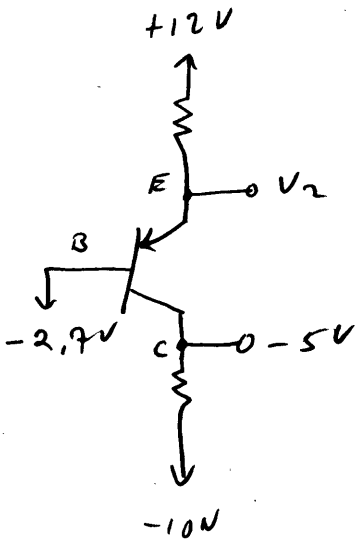
4.19 Large $\beta \Rightarrow i_E \simeq i_C$, $i_B \simeq 0$

(a)



$$I_1 = \frac{10.7V - 0.7V}{10K\Omega} = 1mA$$

(b)



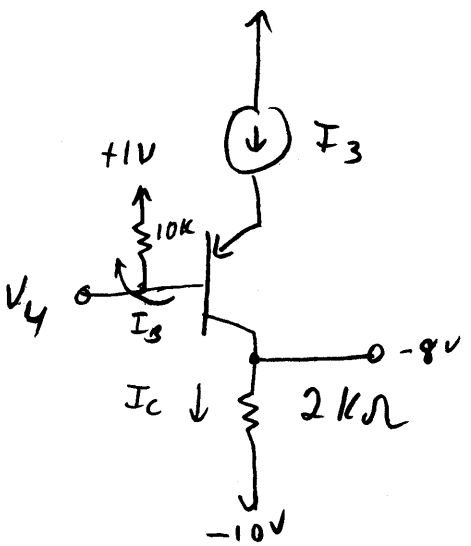
$V_{EB} = V_E - V_B \Rightarrow V_E = V_{EB} + V_B$

$V_B = -2.7V$, so

$V_E = 0.7V - 2.7V = -2.0V$

$V_2 = V_E = -2.0V$

(c)



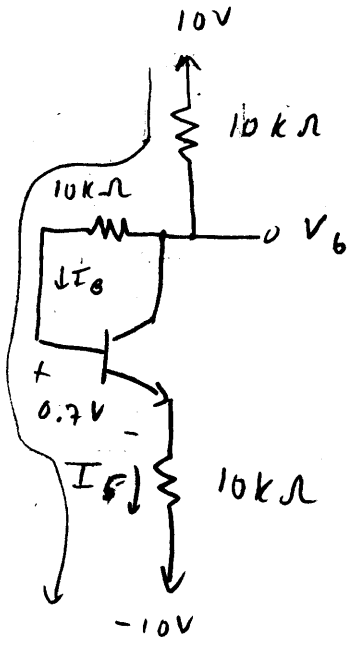
$$I_C = \frac{-8V - (-10V)}{2K} = 1mA$$

$I_E \simeq I_C = 1mA$

$I_3 = I_E = 1mA$

$V_4 = 1V + I_B(10K) = 1V$

(d)



$$20V = I_E R_C + I_B R_B + V_{BE} + I_E R_E$$

$$= I_E R_C + V_{BE} + I_E R_E$$

$(I_E \cong I_E;\quad I_B \cong 0)$

$$I_E = \frac{20 - V_{BE}}{R_C + R_E} =$$

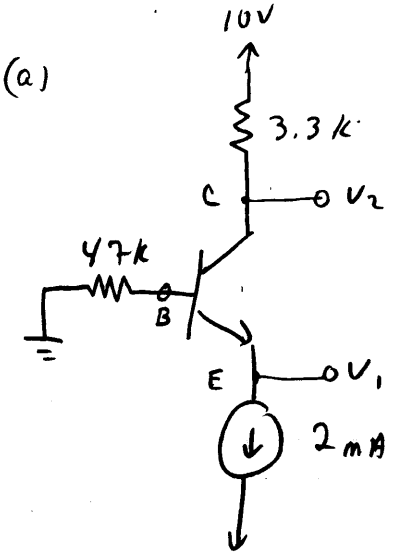
$$= \frac{20 - 0.7}{10k + 10k} = 0.965\,mA$$

$I_S = I_E = 0.965\,mA$

$V_b = 10V - I_C R_C = 10V - (0.965\,mA)(10k\Omega) = 0.35V$

4.36

(a)



$$\alpha = \frac{\beta}{\beta+1} = 0.990$$

$$I_C = \alpha I_E = 1.98\ mA$$

$$V_2 = 10V - I_C R_C$$

$$= 10V - (1.98\ mA)(3.3\ k\Omega) = 3.47V$$

$$I_B = I_C/\beta = 19.8\ \mu A$$

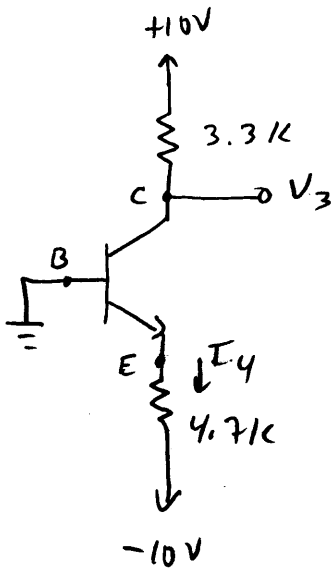
$$V_B = 0 - I_B R_B = (-19.8\ \mu A)(47\ k\Omega)$$

$$= -0.931\ V$$

$$V_1 = V_E = V_B - V_{BE} = -0.931 - 0.700$$

$$= -1.63V$$

(b)



$$V_E = V_B - V_{BE} = 0 - 0.7 = -0.7V$$

$$I_4 = \frac{V_E - (-10V)}{R_E}$$

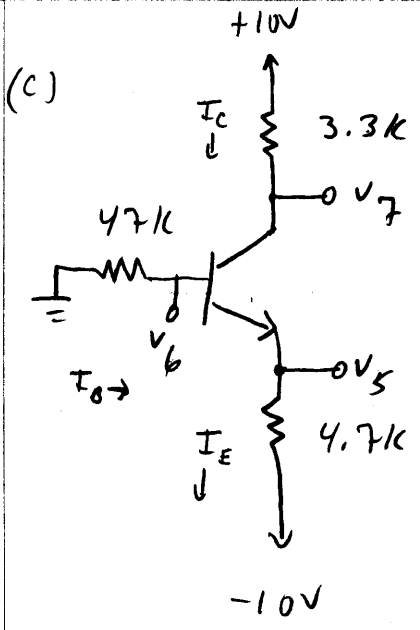
$$I_4 = \frac{-0.7V + 10V}{4.7k} = 1.98\ mA$$

$$I_C = \alpha I_E = \alpha I_4 = 1.96\ mA$$

$$V_3 = 10V - I_C R_C$$

$$= 10V - (1.96\ mA)(3.3\ k\Omega) = 3.53V$$

(c)



KVL from gnd through R_B, V_{BE}, R_E to $-10V$:

$$10\,V = I_B R_B + V_{BE} + I_E R_E$$

$$= I_B R_B + V_{BE} + (\beta + 1) R_E$$

$$I_B = \frac{10 - V_{BE}}{R_B + (\beta+1) R_E}$$

$$= \frac{1.0 - 0.7}{47k + (101)(4.7k)} = 0.019\,mA$$

$$V_6 = 0 - I_B R_B$$

$$= 0 - (0.019\,mA)(47k\Omega)$$

$$= -0.889\,V$$

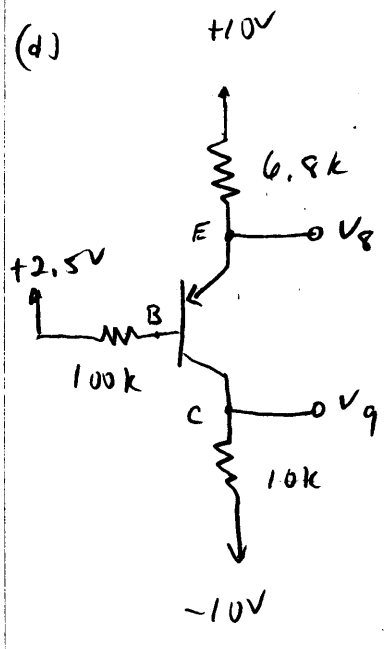
$$V_7 = 10V - I_C R_C = 10V - \beta I_B R_C$$

$$= 10V - (100)(0.019\,mA)(3.3k\Omega) = 3.73\,V$$

$$V_8 = V_B - V_{BE} = V_6 - V_{BE} =$$

$$= -0.889V - 0.7V = -1.59V$$

(d)



Do KVL from +10V through R_E, V_{EB}, R_B to +2.5V:

$$7.5V = I_E R_E + V_{EB} + I_B R_B$$

$$= (\beta+1) I_B R_E + V_{EB} + I_B R_B$$

$$I_B = \frac{7.5V - V_{EB}}{(\beta+1) R_E + R_B}$$

$$= \frac{7.5V - 0.7V}{(101)(6.8k) + 100k} = 8.64\mu A$$

$$V_8 = 10V - I_E R_E = 10V - (\beta+1) I_B R_E$$

$$= 10V - (101)(8.64\mu A)(6.8k)$$

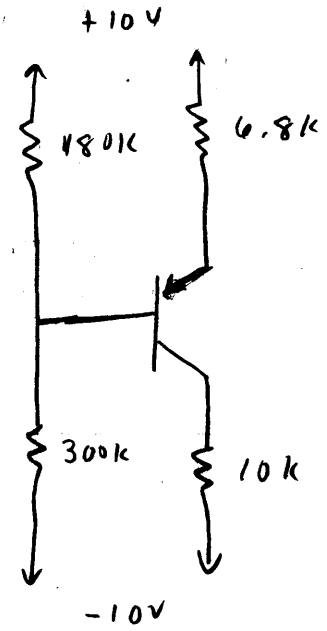
$$= 4.06V$$

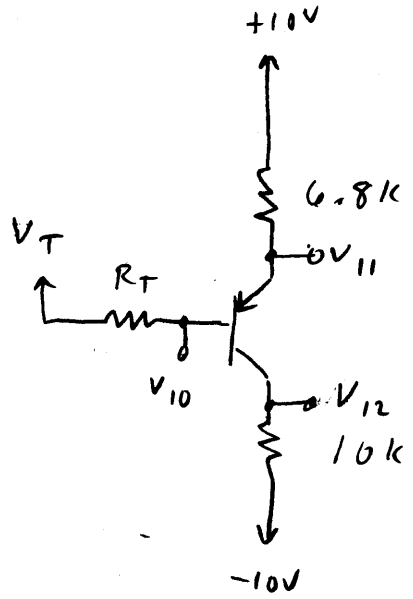
$$V_9 = I_C R_C - 10V = \beta I_B R_C - 10V$$

$$= (101)(8.64\mu A)(10k) - 10V$$

$$= -1.36V$$

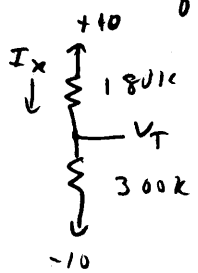
((e)





Simplify bias on base to its Thevenin equivalent:

$R_T = 180K \parallel 300K = 112.5K$



$$I_x = \frac{20V}{180k + 300k} = 41.7\,\mu A$$

$$V_T = 10V - I_x(180k) = 2.5V$$

Do KVL from +10V through R_E, V_{EB}, R_T to V_T

$$10V - V_T = I_E R_E + V_{EB} + I_B R_T = (\beta+1) I_B R_E + V_{EB} + I_B R_T$$

$$I_B = \frac{10V - V_T - V_{EB}}{(\beta+1)R_E + R_T} = 8.51\,\mu A$$

$$V_{10} = I_B R_T + V_T = 3.46V$$

$$V_{11} = 10V - I_E R_E = 10V - (\beta+1) I_B R_E = 4.16V$$

$$V_{12} = I_C R_C - 10V = \beta I_B R_C - 10V = -1.49V$$