EECS 413 PS6 Solution

P6-1

$$I_C = \beta_F I_B = 200 \times 10\mu = \boxed{2\,mA} \quad \#$$

$$I_E = (\beta_F + 1) I_B = 201 \times 10\mu = \boxed{2.01\,mA} \quad \#$$

$$I_E = \left(I_S + \frac{I_S}{\beta_F}\right)\left[e^{\frac{V_{BE}}{V_T}} - 1\right]$$

$$\Rightarrow 2.01m = \left(10^{-17} + \frac{10^{-17}}{200}\right)\left[e^{\frac{V_{BE}}{25m}} - 1\right]$$

$$\Rightarrow V_{BE} = \boxed{0.82\,V} \quad \#$$

P6.2

a)

$$\alpha_F = \frac{I_C}{I_E} = \frac{\beta_F I_B}{I_E}$$

$$\alpha_F = \frac{\beta_F}{1+\beta_F} \Rightarrow \alpha_F + \alpha_F\beta_F = \beta_F$$

$$\Rightarrow \alpha_F = (1-\alpha_F)\beta_F \Rightarrow \beta_F = \frac{\alpha_F}{1-\alpha_F}$$

$$\frac{I_B}{I_E} = \frac{\alpha_F}{\beta_F} = \boxed{1-\alpha_F} \quad \#$$

b)

5% error for $\alpha_F \Rightarrow \alpha_F > 0.90$

$$\frac{\beta_F}{1+\beta_F} > 0.95 \Rightarrow \boxed{\beta_F > 19} \quad \#$$

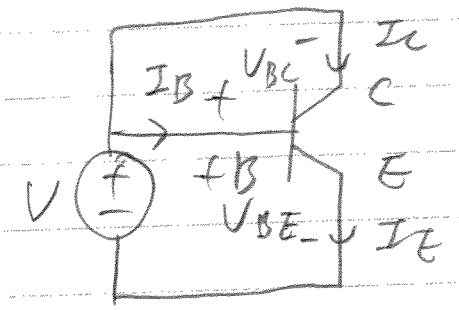
1% error for $\alpha_F \Rightarrow \alpha_F > 0.94$

$$\frac{\beta_F}{1+\beta_F} > 0.99 \Rightarrow \boxed{\beta_F > 99} \quad \#$$

P6.3

(a)

(b)



(c) $V = 0.64V$, $I_C = 275\mu A$, $I_B = 4\mu A$

$I_C = \beta_F I_B \Rightarrow \boxed{\beta_F = 68.75}$ #

$\beta_R = \frac{\alpha_R}{1-\alpha_R} = \frac{0.5}{1-0.5} = \boxed{1}$ #

$I_C = I_S e^{\frac{V_{BE}}{V_T}} \Rightarrow 275\mu = I_S e^{\frac{0.64}{25m}}$

$\Rightarrow I_S = \boxed{2.09 \times 10^{-15} A}$ #

P6.4

$\beta_F = \frac{\alpha_F}{1-\alpha_F} = \frac{0.995}{1-0.995} = 199$

$I_B + I_C = 100\mu A \Rightarrow (1+199) I_B = 100\mu A$

$\Rightarrow \boxed{I_B = 0.5\mu A}$

$\Rightarrow \boxed{I_C = 99.5\mu A}$ #

P6.5 $I_C = \beta_F I_B = \beta_{F0}\left(1+\frac{V_{CE}}{V_A}\right) I_B$

$I_C = 240\mu A$ for $V_{CE} = 5V$

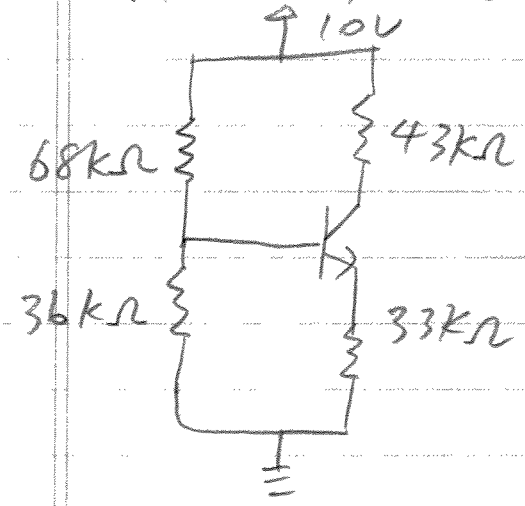
$I_C = 265\mu A$ for $V_{CE} = 10V$

$$\begin{cases} 240\mu = \beta_{F0}\left(1+\frac{5}{V_A}\right)\times 3\mu \\ 265\mu = \beta_{F0}\left(1+\frac{10}{V_A}\right)\times 3\mu \end{cases}$$

$\Rightarrow \boxed{V_A = 43V,\ \beta_{F0} = 71.66}$ #

P6.6

(a) $\beta_F = 50$, $V_{BE} = 0.7V$



$$V_B = \frac{36}{36+68}\times 10 = 3.46V$$

$$R_{eq} = 36k\Omega \,//\, 68k\Omega = 23.54k\Omega$$

$$I_B = \frac{3.46-0.7}{23.54k+(50+1)\times 33k}$$

$$= 1.62\mu A$$

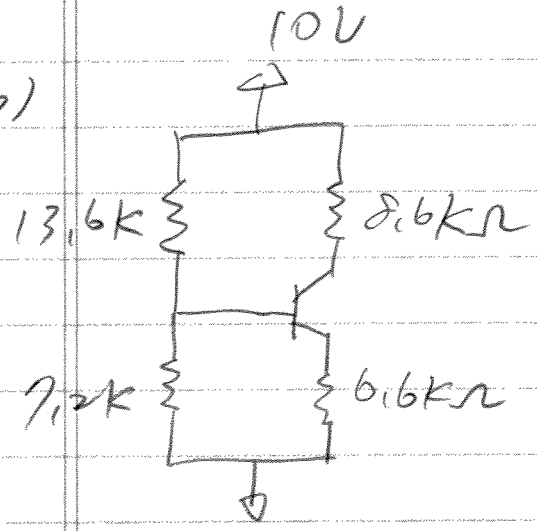
$$I_C = \beta_F I_B = 81\mu A$$

$$V_{CE} = 10 - 43k\times 81\mu - 33k\times(81\mu + 1.62\mu)$$

$$= 3.79V$$

$\boxed{Q \text{ point } (3.79V,\ 81\mu A)}$ #

(b)



$$V_B = 10 \times \frac{7.2}{7.2+13.6} = 3.46V$$

$$R_{eq} = 13.6k \parallel 7.2k = 4.7k\Omega$$

$$I_B = \frac{3.46-0.7}{4.7K+(50+1)\times 6.6K}$$

$$= 8.08\mu A$$

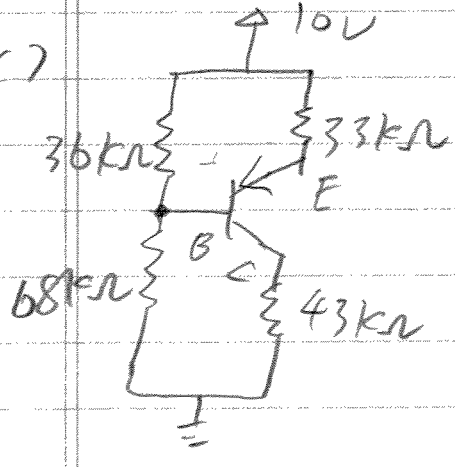
$$I_C = 50 \times I_B = 404.336\mu A$$

$$V_{CE} = 10 - 8.6k \times 404.34\mu - 6.6k \times (8.03\mu + 404\mu)$$

$$= 3.8V$$

Q point (3.8V, 404.34μA) #

(c)



$$V_B = 10 \times \frac{68}{68+36} = 6.54V$$

$$R_{eq} = 36k \parallel 68k = 23.54k\Omega$$

$$I_B = \frac{10-6.54-0.7}{23.54k+(51)\times 33K}$$

$$= 1.61\mu A$$

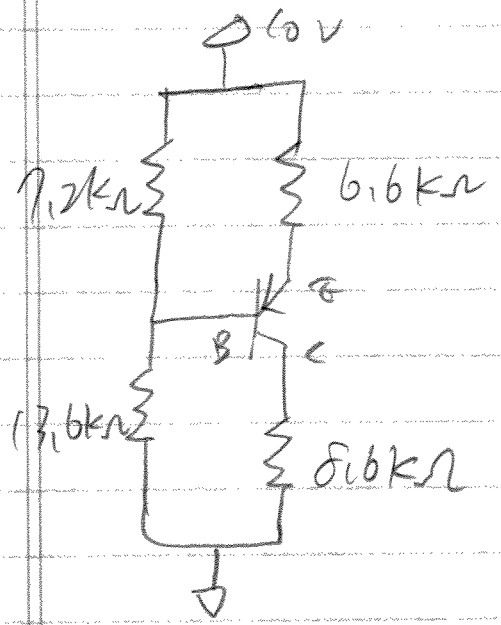
$$I_C = 50 \times I_B = 80.86\mu A$$

$$V_{EC} = 10 - 33k \times (1.61\mu + 80.86\mu) - 80.86\mu \times 43k$$

$$= 3.8V$$

Q point (3.8V, 80.86μA) #

(d)



$$V_B = 10 \times \frac{13.6}{13.6+7.2} = 6.54V$$

$$R_{eq} = 7.2K \parallel 13.6K = 4.7k\Omega$$

$$I_B = \frac{10 - 6.54 - 0.7}{4.7k + 6.6K \times 51}$$

$$= 8.09\mu A$$

$$I_C = 50 \times I_B = 404.34\mu A$$

$$V_{EC} = 10 - 6.6K \times (404.34\mu + 8.09\mu) - 8.6K \times (404.34\mu)$$

$$= 3.8V$$

Q point (3.8V, 404.34μA)

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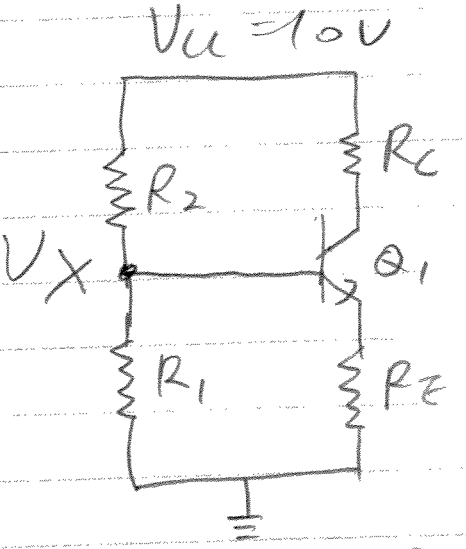
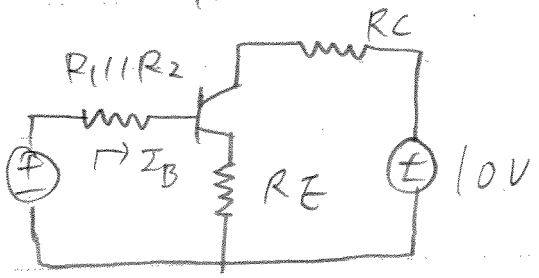
P6.7



$R_1=6.2k\Omega$, $R_2=12k\Omega$
$R_C=5.1k\Omega$, $R_E=7.5k\Omega$
$\beta_F=100$, $V_{CC}=10V$

$\equiv$



$$V_X = V_{CC} \times \frac{R_1}{R_1+R_2} = 10 \times \frac{6.2}{6.2+12} = 3.4\,V$$

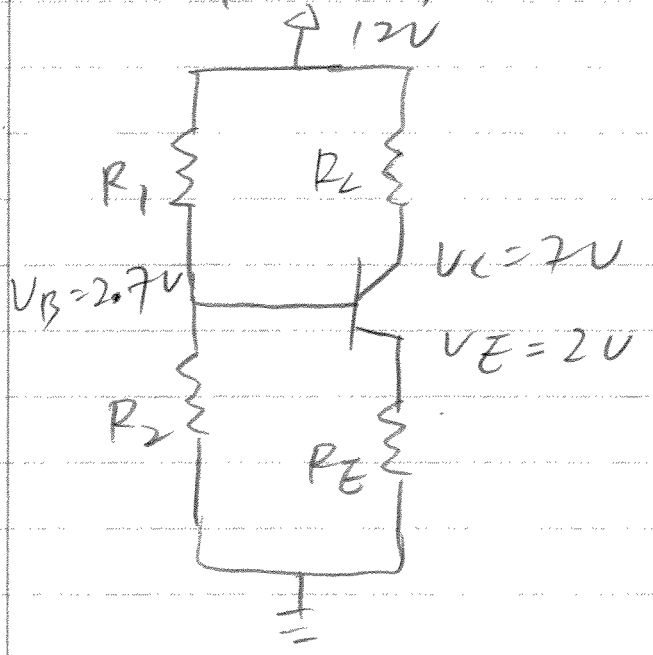
$$R_1 \| R_2 = 6.2k \| 12k = 4.08k\Omega$$

$$I_C = \beta_F I_B = 100 \times \frac{3.4-0.7}{4.08k+101\times 7.5k} = 354.5\mu A$$

$$V_{CE} = 10 - 354.5\times10^{-6}\times 5.1\times10^{3}$$
$$-354.5\times10^{-6}\times\frac{101}{100}\times 7.5\times10^{3}$$
$$= 5.5\,V$$

Q-point : (5.5V, 354.5μA) #

P6.8 $I_C = 1mA$, $V_{CE} = 5V$, $V_E = 2V$
$V_{CC} = 12V$, $\beta_F = 100$
$V_{BE,on} = 0.7V$



$$R_C = \frac{12-7}{10^{-3}} = 5k\Omega$$

$$R_E = \frac{2}{I_B + I_C} = \frac{2}{10^{-3}(1+100)} \approx 1.98k\Omega$$

$$I_B = \frac{I_C}{\beta_F} = 10\mu A = \frac{12-2.7}{R_1} = \frac{2.7}{R_2}$$

Choose $R_2 = 50k\Omega$

$R_1 = 165.3k\Omega$

$R_1 = 145.3k\Omega$
$R_2 = 50k\Omega$
$R_C = 5k\Omega$
$R_E = 1.98k\Omega$

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