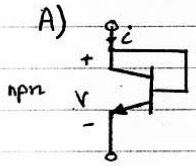
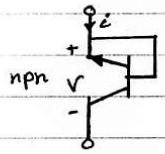
Answers to Chapter 5

5.32

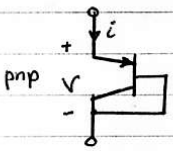
A)



$V_{BE} > 0$ (on)
$V_{BC} = 0$ (off)
↳ forward active

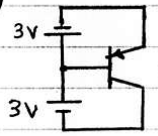


$V_{BE} = 0$ (off)
$V_{BC} > 0$ (on)
↳ reverse active



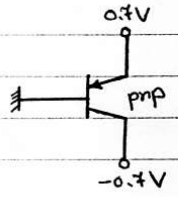
$V_{EB} > 0$ (on)
$V_{BC} = 0$ (off)
↳ forward active

B)



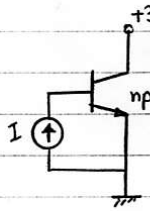
$V_{EB} = -3V$ (off)
$V_{CB} = -3V$ (off)
↳ cutoff

C)

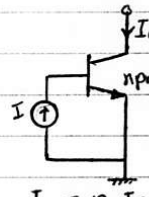


$V_{EB} = 0.7$ V (on)
$V_{CB} = -0.7$V (off)
↳ forward active

D)



BE junction (on)
$\therefore V_{BE} \simeq 0.7$ V (apx)
$V_{BC} \simeq 0.7 - 3 = -2.3$V (off)
↳ forward active



BE junction (on)
$V_{BE} = 0.7$ V
$\therefore I_C = 0$ but $I_B, I_E \neq 0$
$\therefore$ The BJT is on, but not forward active
$\therefore$ It's saturated

$I_C < \beta_F I_B$

5.61

PNP $V_{EB} = 0.7$V $V_{CB} = -0.7$V $\Rightarrow$ forward active

$\therefore I_C = \beta_F I_B \Rightarrow \beta_F = \frac{2.5\,mA}{50\,\mu A} = 50$

Also $I_C = I_S\, e^{(V_{EB}/V_T)} \Rightarrow I_S = \frac{2.5\,mA}{e^{(0.7/0.025)}} = 1.73\,fA$

5.65

NPN $V_{BE} = -0.7$V, $V_{BC} = 0.7$V $\Rightarrow$ reverse active

$\therefore I_C = -(\beta_R + 1) I_B \Rightarrow \beta_R = -\frac{I_C}{I_B} - 1 = -\frac{-75\,\mu A}{50\,\mu A} - 1 = 0.5$

$I_E = -I_S\, e^{(V_{BC}/V_T)} = I_B + I_C = -25\,\mu A$

$\therefore I_S = -\frac{-25\,\mu A}{e^{(0.7/0.025)}} = 17.3 \times 10^{-18}$ A

5.73

A) NPN Forward active

$I_C = \beta_F I_B = I_S e^{(V_{BE}/V_T)} \Rightarrow V_{BE} = V_T \ln\left(\frac{50 \times 250\mu A}{10\,fA}\right) = 0.812\ V$

B) NPN Saturation ($\because I_C < \beta_F I_B$)

Use eq. 5.53 $V_{BE} = V_T \ln \frac{I_B + (1-\alpha_R) I_C}{I_S\left[\frac{1}{\beta_F} + (1-\alpha_R)\right]} = 0.025 \ln \frac{250 \times 10^{-6} + 0}{10^{-16}\left[\frac{1}{50} + (1 - \frac{0.5}{1.5})\right]} = 0.723$

eq. 5.54 $V_{CEsat} = V_T \ln\left[\left(\frac{1}{\alpha_R}\right) \frac{1 + \frac{I_C}{(\beta_{FH}+1) I_B}}{1 - \frac{I_C}{\beta_F I_B}}\right] \Rightarrow V_{CEsat} = V_T \ln\left(\frac{1}{\alpha_R}\right) = 27.5\ m$

5.74

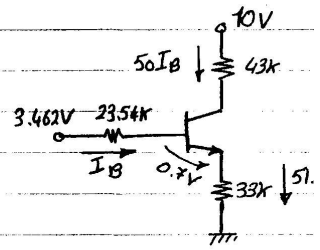
A) $I_C = I_S\left[e^{(V_{BE}/V_T)} - 1\right]\left(1 + \frac{V_{CE}}{V_A}\right) = 10^{-16}\left[e^{(0.72/0.025)} - 1\right]\left(1 + \frac{10}{65}\right) = 371\ \mu A$

B) $I_C = 10^{-16}\left[e^{(0.72/0.025)} - 1\right] = 322\ \mu A$

C) $\frac{I_{C_1}}{I_{C_2}} = \frac{371\mu A}{322\mu A} = 1.15$

5.82

A) The circuit can be reduced as follows:



KVL $3.462 - (23.54k)I_B - 0.7 - (33k)(51I_B) = 0$

$\Rightarrow I_B = 1.618\,\mu A$, $I_C = 50I_B = 80.9\,\mu A$

KVL $10 - (43k)(80.9\mu A) - V_{CE} - (33k)(82.5\mu A) = 0$

$\Rightarrow V_{CE} = 3.797V$

$\therefore Q = (80.9\mu A, 3.797V)$

B) After simplifying the circuit the same way

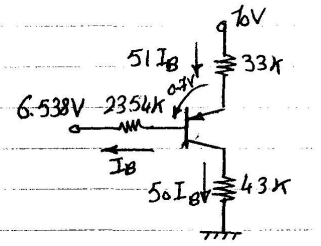
KVL $3.462 - (4.708k)I_B - 0.7 - 16.6k)(51I_B) = 0 \Rightarrow I_B = 8.09\,\mu A$

KVL $10 - (8.6k)I_C - V_{CE} - (6.6k)I_E = 0 \Rightarrow V_{CE} = 3.797V$

$\therefore Q = (405\mu A, 3.797V)$

C) KVL $10 - (33k)(51I_B) - 0.7 - (23.54k)(I_B) - 6.538 = 0$

$\Rightarrow I_B = 1.618\,\mu A$, $I_C = 80.9\,\mu A$



KVL $10 - (33k)(51I_B) - V_{EC} - (43k)(50I_B) = 0$

$\Rightarrow V_{EC} = 3.797V$

$\therefore Q = (80.9\mu A, 3.797V)$

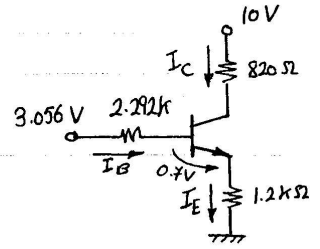
D) Using same procedure

$\Rightarrow I_B = 8.092\,\mu A$, $I_C = 404.6\,\mu A$

& $V_{EC} = 3.797V$

$\therefore Q = (404.6\mu A, 3.797V)$

5.91



First we need to simplify the ckt. using Thevenin eq.

From the c/c's we need to calculate β_F

so if we choose $V_{CE} = 5V \Rightarrow \beta_F \simeq \frac{5mA}{60\mu A} = 83$

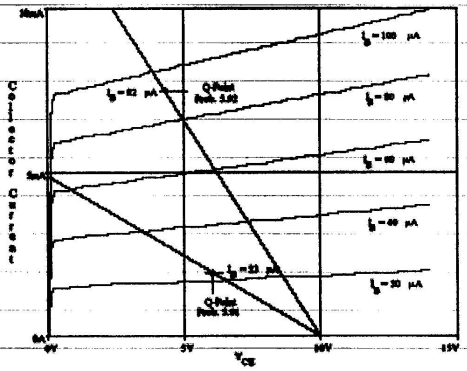
KVL $V_{CE} = 10 - 820I_C - 1200I_E = 10 - 2034I_C$

Draw this loadline on the c/c's & then calculate I_B

KVL $3.056 - (2.292k)I_B - 0.7 - (1.2k)(83+1)I_B = 0 \Rightarrow I_B = 23\mu A$

So using the given c/c's :

$Q = (1.9mA, 6V)$



5.95

A) $5 - V_{EC} - (I_C + I_B)R_C - (-5) = 0 \Rightarrow R_C = \frac{10 - V_{EC}}{I_E} = \frac{7V}{I_E}$

but $I_E = \frac{\beta_F + 1}{\beta_F} I_C = 10.13\,mA \Rightarrow R_C = 691\,\Omega \rightarrow 680\,\Omega$ (practical value)

KVL $V_{EC} = V_{EB} + I_B R_B \Rightarrow R_B = \frac{V_{EC} - V_{EB}}{I_B} = \frac{3 - 0.7}{0.133mA} = 17.3k\Omega \rightarrow 18\,k\Omega$

B) KVL $5 - 0.7 - (18k)I_B - (0.68k)(41 I_B) - (-5) = 0 \Rightarrow I_B = 2027\,\mu A$

$\therefore I_C = 8.108\,mA$

KVL $5 - V_{EC} - (0.68k)(41 I_B) = 0 \Rightarrow V_{EC} = 4.35\,V$

$\Rightarrow Q = (8.11\,mA, 4.35V)$

5.98

Read section 5.13

A) $I = I_{REF} \frac{\left[1 + \frac{V_{CE2}}{V_A}\right]}{\left[1 + \frac{V_{BE}}{V_A} + \frac{2}{\beta_{F0}}\right]} = \frac{18V - 0.7V}{470\,k} \frac{(1+0)}{(1+0+2/40)} = 35.1\,\mu A$

B) $I = \frac{18V - 0.7V}{470\,k} \frac{1 + 18/35}{1 + \frac{0.7}{35} + \frac{2}{40}} = 52.1\,\mu A$

C) ⓐ $I = I_{REF} \frac{\left[1 + V_{EC2}/V_A\right]}{\left[1 + \frac{V_{EB}}{V_A} + \frac{2}{\beta_{F0}}\right]} = \frac{18V - 0.7V}{470\,k} \frac{1}{1 + 2/20} = 33.5\,\mu A$

ⓑ $I = \frac{18V - 0.7V}{470\,k} \frac{1 + 18/35}{1 + \frac{0.7}{35} + 2/20} = 49.8\,\mu A$