EE 321

Fall 2002

Homework #8

Solutions

4.23

$$i_c = I_s e^{\frac{v_{BE}}{V_T}} \left(1 + \frac{v_{CE}}{V_A}\right) = 10^{-15} e^{v_{BE}/0.025} \left(1 + \frac{v_{CE}}{100}\right)$$

$$i_c = \underbrace{I_s e^{\frac{v_{BE}}{V_T}}}_{\text{y-intercept}} + \underbrace{\frac{I_s e^{v_{BE}/V_T}}{V_A}}_{\text{slope}} v_{CE}$$

v_{BE} (V)	0.65	0.7	0.72	0.73	0.74
Intercept (mA)	0.20	1.45	3.22	4.80	7.16
slope (mA/V)	0.002	0.014	0.032	0.048	0.072

See next page for plot

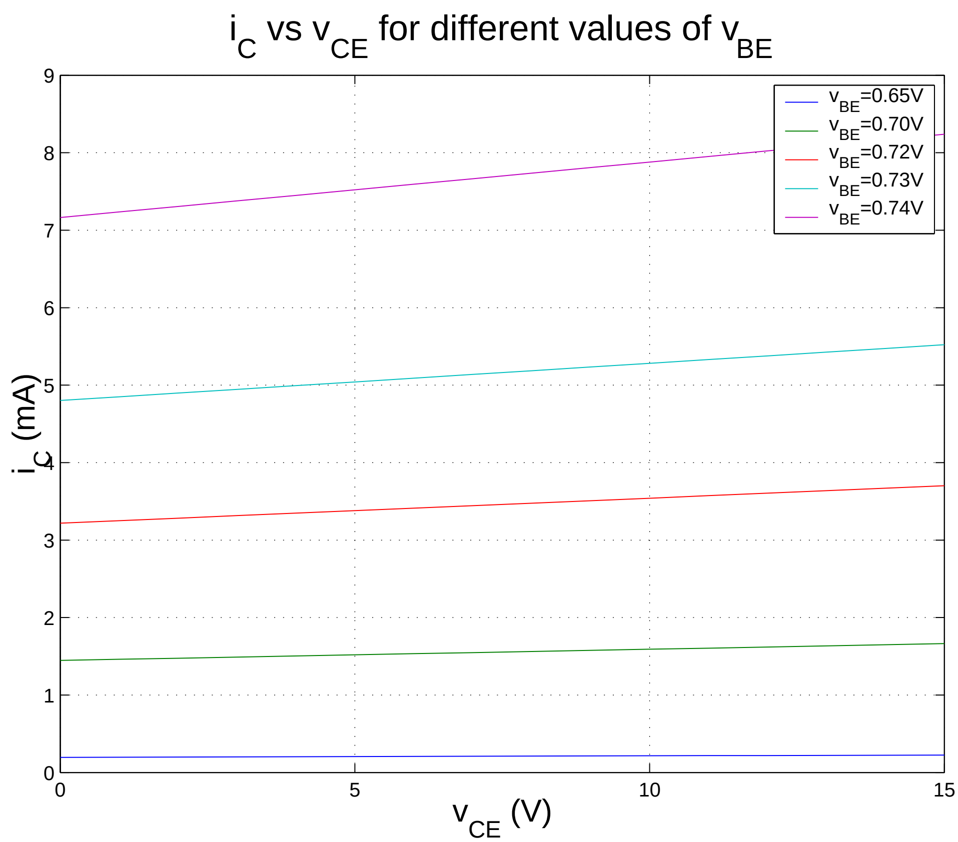
4.26

$$r_o = \frac{1}{\text{slope}} = \frac{1}{3 \times 10^{-5} \mho} = 33.3\ k\Omega$$

$$r_o = \frac{V_A}{I_C} \Rightarrow V_A = r_o I_C = (33.3 k\Omega)(3 mA) = 100 V$$

$$r_o = \frac{V_A}{I_C} = \frac{100}{30 mA} = 3.33 K\Omega$$

```
IS=1e-15;
VT=25e-3;
vCE=0:1:15;
VA = 100;
vbe = [0.65;0.7;0.72;0.73;0.74];
for ii=1:length(vbe)
  iC(ii,:) = IS*exp(vbe(ii)/VT)*(1+vCE/VA);
end
plot(vCE,iC*1000)
legend('v_{BE}=0.65V','v_{BE}=0.70V','v_{BE}=0.72V','v_{BE}=0.73V','v_{BE}=0.74V')
xlabel('v_{CE} (V)','FontSize',16)
ylabel('i_{C} (mA)','FontSize',16)
grid
title('i_C vs v_{CE} for different values of v_{BE}','FontSize',18);
```



4.29 In the active region the plot of i_C vs. v_{CE} is a straight line

$\therefore \quad i_C = m\, v_{CE} + b$

$$m = \frac{\text{rise}}{\text{run}} = \frac{i_{C_2} - i_{C_1}}{v_{CE_2} - v_{CE_1}} = \frac{1.1\,mA - 1.0\,mA}{10\,V - 2\,V} = 0.0125\,mA/V$$

$$b = i_{C_1} - m\, v_{CE_1} = 1\,mA - (0.0125\,mA/V)(2V) = 0.975\,mA$$

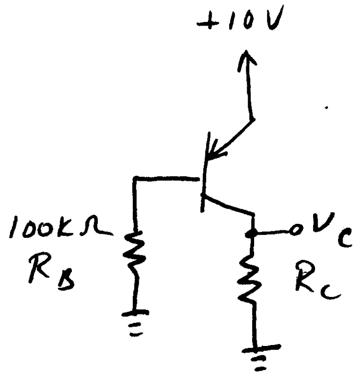
$$v_{CE} = \frac{i_C - b}{m} \qquad \text{For } i_C = 0, \quad v_{CE} = \frac{-b}{m} = \frac{-0.975\,mA}{0.0125\,mA/V} = \underline{\underline{78\,V}}$$

OR

$$r_o = \frac{1}{\text{slope}} = \frac{\Delta v_{CE}}{\Delta i_C} = \frac{10\,V - 2\,V}{1.1\,mA - 1.0\,mA} = 80\,k\Omega$$

$$r_o = \frac{V_A}{I_C} \Rightarrow V_A = r_o I_C = (80\,k\Omega)(1\,mA) = \underline{\underline{80\,V}}$$

4.38



$V_B = V_E - 0.7V = 10V - 0.7V = 9.3V$

$I_B = V_B / R_B = 9.3V / 100k\Omega = 93\mu A$

$I_C = \beta I_B = (50)(93\mu A) = 4.65 mA$

$V_C = I_C R_C \Rightarrow R_C = V_C / I_C = 5V / 4.65 mA = 1.075 k\Omega$

For $\beta = 100$, I_B will be the same, so

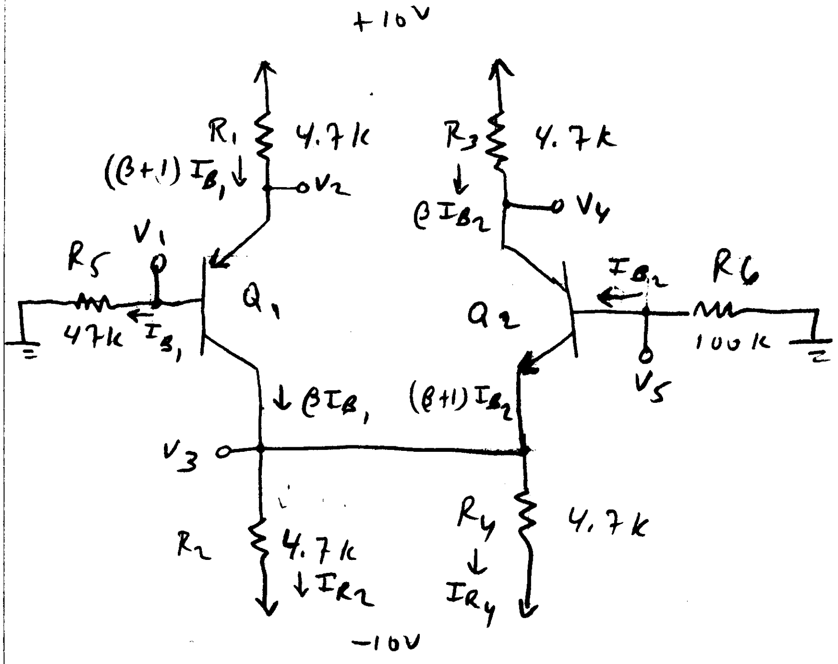
$I_C = \beta I_B = (100)(93\mu A) = 9.3 mA$

$V_C = I_C R_C = (9.3mA)(1.075 k\Omega) = +10V$

This is impossible - the transistor will not be in active mode — it will be saturated

$V_C \simeq 9.8V$

4.40



(a) With $\beta = \infty$ $I_{B_1} = I_{B_2} = 0$, $I_{C_1} = I_{E_1}$ and $I_{E_2} = I_{E_2}$

$V_1 = 0$ (because $I_{B_1} = 0$)

$V_2 = V_1 + V_{EB_1} = 0 + 0.7V = 0.7V$

$V_5 = 0$ (because $I_{B_2} = 0$)

$V_3 = V_5 - V_{BE_2} = 0 - 0.7V = -0.7V$

Cannot find V_4 because we do not know I_{C_2}.

(WE KNOW $I_{R_2} = I_{R_4} = 9.3V/4.7k$, and $I_{C_1} + I_{E_2} = I_{R_2} + I_{R_4}$,

THERE IS NO WAY TO DETERMINE I_{C_1}, I_{E_2} or I_{C_2})

(b) $\beta = 100$

KVL from +10V through R_1, V_{EB_1}, R_5 to ground:

$$10V = (\beta+1) I_{B_1} R_1 + V_{EB_1} + I_{B_1} R_5 \Rightarrow I_{B_1} = \frac{10V - 0.7V}{(\beta+1) R_1 + R_5} = 0.0178\,mA$$

KVL from GND through R_6, V_{BE_2}, R_4 to $-10V$:

① $I_{B_2} R_6 + V_{BE_2} + I_{R_4} R_4 = 10V$

KCL at node V_3:

② $\beta I_{B_1} + (\beta+1) I_{B_2} = I_{R_2} + I_{R_4}$

R_2 and R_4 are same size and same resistance, so

③ $I_{R_2} = I_{R_4}$

Eq 1, 2, 3 are 3 eqns with 3 unknowns (I_{B_2}, I_{R_2}, I_{R_4})

Solve these to find

$I_{B_2} = 0.0152$ mA

$I_{R_4} = 1.655$ mA

$I_{R_2} = 1.655$ mA

$V_1 = I_{B_1} R_5 = 0.837$ V

$V_2 = V_1 + V_{EB_1} = 1.54$ V

$V_3 = I_{R_2} R_2 - 10\text{V} = -2.22$V

$V_4 = 10\text{V} - \beta I_{B_2} R_3 = 2.856$V

$V_5 = 0\text{V} - I_{B_2} R_6 = -1.52$V

Consistency Check - calculate V_2 and V_3 other ways:

$V_3 = V_5 - V_{BE_2} = -2.22$V ✓

$V_2 = 10\text{V} - (\beta+1) I_{B_1} R_2 = 1.55$V ✓