Solutions to Tutorial Sheet – 5

1. $I_C = \alpha_0 I_E = 0.98 \times 2 = \mathbf{1.96\ mA}$; $I_B = I_E - I_C = (2 - 1.96) = 0.04\ \text{mA} = \mathbf{40\ \mu A}$

2. $I_E = I_B + I_C = 2.9 + 0.1 = 3\ \text{mA}$; $\alpha_0 = I_C / I_E = 2.9/3 = \mathbf{0.97}$

3. $I_C = I_E\,\alpha_0 = 2 \times 0.985 = \mathbf{1.97\ mA}$; $I_B = I_E - I_C = (2 - 1.97)\ \text{mA} = \mathbf{30\ \mu A}$

4. $I_{C(INJ)} = \beta_0 I_B = 80 \times 40\ \mu\text{A} = 3.2\ \text{mA}$; $I_C = I_{C(INJ)} + I_{CEO} = 3.2 + I_{CBO}(1+\beta_0) = 3.605\ \text{mA}$ → $I_C = \beta_0 I_B + I_{CEO}$

$I_E = I_B + I_C = (0.040 + 3.605)\ \text{mA} = \mathbf{3.645\ mA}$

5. $I_C = \alpha_0 I_E + I_{CO} = (0.995 \times 10 + 0.0005)\ \text{mA} = \mathbf{9.9505\ mA}$; $I_B = I_E - I_C = (10 - 9.9505)\ \text{mA} = \mathbf{49.5\ \mu A}$

$\beta_0 = \dfrac{\alpha_0}{1-\alpha_0} = \dfrac{0.995}{0.005} = \mathbf{199}$; $I_{CEO} = I_{CO}(1+\beta_0) = 0.5 \times (1+199)\ \mu\text{A} = \mathbf{100\ \mu A}$

6. $I_{CEO} = I_C - \beta_0 I_B = (5 - 140 \times 0.035)\ \text{mA} = 0.1\ \text{mA}$; $\therefore\ I_{CO} = I_{CBO} = \dfrac{I_{CEO}}{1+\beta_0} = \dfrac{100\ \mu\text{A}}{141} = \mathbf{0.71\ \mu A}$

7. $I_{CEO} = (1+\beta_0) I_{CBO}$; or $\beta_0 + 1 = \dfrac{I_{CEO}}{I_{CBO}} = \dfrac{16}{0.1} = 160$; $\therefore\ \beta_0 = 159$; $\therefore\ \alpha_0 = \dfrac{\beta_0}{1+\beta_0} = \dfrac{159}{160} = \mathbf{0.99375}$

8. $I_{C(INJ)} = I_C - I_{CO} = 21.995\ \text{mA}$

(a) $\alpha_0 = \mathbf{0.995}$ ($\because$ 99.5 % of carriers cross the BC junction)

(b) $I_E = \dfrac{I_{C(INJ)}}{\alpha_0} = \dfrac{21.995}{0.995} = \mathbf{22.1055\ mA}$; (c) $\alpha_0 = \dfrac{I_C}{I_E} = \dfrac{22}{22.1055} = \mathbf{0.9952}$

9. $I_C = \alpha_0 I_E + I_{CO} = (0.99 \times 4 + 0.003)\ \text{mA} = \mathbf{3.963\ mA}$; $I_B = I_E - I_C = (4 - 3.963)\ \text{mA} = \mathbf{37\ \mu A}$ ($I_{CO} \to I_{CBO}$)

10.(a) $I_B = 0.85\%\ \text{of}\ I_E = 0.0085 \times 8.8\ \text{mA} = \mathbf{74.8\ \mu A}$; (b) $I_C = I_E - I_B = 8.8 - 0.0748 = \mathbf{8.7252\ mA}$

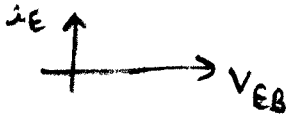
(c) $I_{C(INJ)} = I_C - I_{CO} = 8.7252 - 0.0002 = 8.725\ \text{mA}$; $\therefore\ \alpha_0 = \dfrac{I_{C(INJ)}}{I_E} = \dfrac{8.725}{8.8} = \mathbf{0.991477}$

(d) $\alpha_0(\text{appx}) = \dfrac{I_C}{I_E} = \dfrac{8.7252}{8.8} = \mathbf{0.9915}$

11.(a) $\beta_0 = \dfrac{\alpha_0}{1-\alpha_0} = \dfrac{0.987}{0.013} = \mathbf{75.92}$; $I_{CEO} = \dfrac{I_{CBO}}{1-\alpha_0} = \dfrac{52 \times 10^{-9}}{0.013} = \mathbf{4\ \mu A}$

(b) $I_C = \beta_0 I_B + I_{CEO} = 75.92 \times 40 \times 10^{-6} + 4 \times 10^{-6}\ \text{A} = \mathbf{3.0408\ mA}$

(c) $I_C = \beta_0 I_B = \mathbf{3.0368\ mA}$

12. $r_i = \dfrac{\Delta V_{BE}}{\Delta I_E} = \dfrac{200\ \text{mV}}{5\ \text{mV}} = \mathbf{40\ \Omega}$ → 

13.(a) $I_C = \dfrac{V_{CC} - V_{CB}}{R_C} = \dfrac{15-10}{3.3 \times 10^3} = \mathbf{1.515\ mA}$; (b) $V_{CB} = V_{CC} - I_C R_C = 15 - 1.4 \times 3.3 = \mathbf{10.38\ V}$

14. $I_C = \beta_0 I_B = \beta_0 \times \dfrac{V_{CC}}{R_B} = \dfrac{60 \times 10}{100 \times 10^3} = \mathbf{6\ mA}$; $I_{C(sat)} = \dfrac{V_{CC}}{R_C} = \dfrac{10}{1\ \text{k}\Omega} = 10\ \text{mA} \Rightarrow\ I_C = \mathbf{6\ mA}$;

$V_{CE} = V_{CC} - I_C R_C = 10 - 6 \times 1 = \mathbf{4\ V}$

15. $V_{CC} = V_{CE} + I_C R_C$ or $14 = 7 + I_C \times 4$ $\Rightarrow$ $I_C = \mathbf{1.75\ mA}$

$I_B = \dfrac{I_C}{\beta_0} = \dfrac{1.75\ \text{mA}}{100} = 17.5\ \mu\text{A}$; $R_B = \dfrac{V_{CC} - V_{BE}}{I_B} = \dfrac{14 - 0.6}{17.5\ \mu\text{A}} = \mathbf{765\ k\Omega}$

16. $I_B = \dfrac{V_{CC} - V_{BE}}{R_B} = \dfrac{10}{200\ \text{k}\Omega} = 50\ \mu\text{A}$; $I_C = \beta_0 I_B = 100 \times 50\ \mu\text{A} = 5\ \text{mA}$

$\therefore\ V_{CE} = V_{CC} - I_C R_C = 10 - 5 \times 1 = \mathbf{5\ V}$

17. $I_B = \dfrac{I_C}{\beta_0} = \dfrac{2\ \text{mA}}{200} = 0.01\ \text{mA}$; $\therefore\ R_B = \dfrac{V_{CC}}{I_B} = \dfrac{9\ \text{V}}{0.01\ \text{mA}} = \mathbf{900\ k\Omega}$; $V_{CE} = -[V_{CC} - I_C R_C] = -[9 - 2 \times 1.5] = \mathbf{-6\ V}$ how?

18. $I_B = \dfrac{V_{CC} - V_{BE}}{R_B} = \dfrac{(16 - 0.2)\ \text{V}}{790\ \text{k}\Omega} = 0.02\ \text{mA}$; $I_C = \beta_0 I_B = 100 \times 0.02\ \text{mA} = \mathbf{2\ mA}$

$\therefore \quad V_{CE} = -[V_{CC} - I_C R_C] = -[6 - 2\times 5] = \mathbf{-6\ V}$

19. $I_B = \dfrac{V_{CC}}{R_B} = \dfrac{9\ \text{V}}{100\ \text{k}\Omega} = 0.09\ \text{mA}$; $I_C = \beta_0 I_B = 40\times 0.09\ \text{mA} = \mathbf{3.6\ mA}$; $\therefore \quad V_{CE} = V_{CC} - I_C = \mathbf{5.4\ V}$

20. $I_B = \dfrac{V_{CC} - V_{BE}}{R_B + (1+\beta_0)R_C} \cong \dfrac{12\ \text{V}}{(60 + 61\times 3)\ \text{k}\Omega} = 0.0494\ \text{mA}$ $\quad [R_C(I_B + I_C) + R_B I_B + V_{BE} = V_{CC}]$

$I_C = \beta_0 I_B = 60\times 0.0494\ \text{mA} = 2.96\ \text{mA} \cong \mathbf{3\ mA}$; $\therefore \quad V_{CE} = V_{CC} - I_C R_C = 12 - 3\times 3 = \mathbf{3\ V}$

21. $I_C R_C = V_{CC} - V_{CE} = V_{CC} - 0.5V_{CC} = 0.5V_{CC} = 0.5\times 30 = 15\ \text{V}$ (Neglecting I_B)

$\therefore I_C = \dfrac{15\ \text{V}}{5\ \text{k}\Omega} = 3\ \text{mA}$; $I_B = \dfrac{I_C}{\beta_0} = \dfrac{3\ \text{mA}}{40} = 0.075\ \text{mA}$; $\therefore R_B = \dfrac{V_{CE}}{I_B} = \dfrac{15\ \text{V}}{0.075\ \text{mA}} = \mathbf{200\ k\Omega}$

22. (a) $I_B = \dfrac{V_{CC} - V_{BE}}{R_B + (1+\beta_0)R_C} \cong \dfrac{(15 - 0.7)\ \text{V}}{[215 + (1+100)\times 5]\ \text{k}\Omega} \approx 0.02\ \text{mA}$

$I_C = \beta_0 I_B = 100\times 0.02\ \text{mA} = \mathbf{2\ mA}$ and $V_{CE} = V_{CC} - I_C R_C = \mathbf{5\ V}$

(b) $I_B = \dfrac{(15 - 0.7)\ \text{V}}{[215 + (1+300)5]\ \text{k}\Omega} = 0.0083\ \text{mA}$; $I_C = \beta_0 I_B \approx \mathbf{2.5\ mA}$ and $V_{CE} = 15 - 2.5\times 5 = \mathbf{2.5\ V}$

23. $I_B = \dfrac{V_{CC}}{R_B + \beta_0 R_E} = \dfrac{9\ \text{V}}{[50 + 80\times 0.5]\ \text{k}\Omega} = 0.1\ \text{mA} \Rightarrow \quad I_C = \beta_0 I_B = 80\times 0.1\ \text{mA} = \mathbf{8\ mA}$;

$V_{CE} = V_{CC} - I_C(R_C + R_E) = 9 - 8\times(0.25 + 0.5) = \mathbf{3\ V}$

24. $I_B = \dfrac{V_{CC}}{R_B + \beta_0 R_E} = \dfrac{20\ \text{V}}{[400 + 100\times 1]\ \text{k}\Omega} = 0.04\ \text{mA}$; $I_C = \beta_0 I_B = 100\times 0.04\ \text{mA} = \mathbf{4\ mA}$

$\therefore \quad V_{CE} = V_{CC} - I_C(R_C + R_E) = 20 - 4\times(2+1) = \mathbf{8\ V}$

25. $I_B = \dfrac{V_{CC}}{R_B + \beta_0 R_E} = \dfrac{180\ \text{V}}{[50 + 56\times 0.75]\ \text{k}\Omega} = 0.1956\ \text{mA} \Rightarrow I_C = \beta_0 I_B = \mathbf{10.95\ mA}$

$\therefore \quad V_{CE} = V_{CC} - I_C(R_C + R_E) = 18 - 10.95\times(0.5 + 0.75) = \mathbf{4.31\ V}$

26. $V_{CE} = V_{CC} - I_C(R_C + R_E)$ or $3.8 = 10 - 5(0.5 + R_E) \quad \Rightarrow \quad R_E = \mathbf{740\ \Omega}$. Now,

$I_B = \dfrac{I_C}{\beta_0} = 0.05\ \text{mA}$; $I_B = \dfrac{V_{CC} - V_{BE}}{R_B + \beta_0 R_E}$ or $0.05 = \dfrac{10 - 0.3}{R_B + 100\times 0.740} \quad \Rightarrow \quad R_B = \mathbf{120\ k\Omega}$

27. $V_B = V_2 = \dfrac{R_2}{R_1 + R_2}\times V_{CC} = \dfrac{5}{40+5}\times 12 \approx 1.3\ \text{V}$; $\therefore \quad V_E = V_2 - V_{BE} = 1.3 - 0.3 = 1.0\ \text{V}$ and

$I_E = \dfrac{V_E}{R_E} = 1\ \text{mA}$; $I_C \cong \mathbf{1\ mA}$; $\therefore \quad V_{CE} = V_{CC} - I_C(R_C + R_E) = 12 - 1\times(5+1) = \mathbf{6\ V}$

28. $V_{TH} = \dfrac{R_2}{R_1 + R_2} V_{CC} = 1.3\ \text{V}$ and $R_{TH} = \dfrac{R_1 R_2}{R_1 + R_2} = 4.44\ \text{k}\Omega$

$\therefore I_B = \dfrac{V_{TH} - V_{BE}}{R_{TH} + \beta_0 R_E} = \dfrac{1.3 - 0.3}{4.44 + 60\times 1} = 0.01552\ \text{mA}$; $\therefore \quad I_C = \beta_0 I_B = 60\times 0.01552 = \mathbf{0.93\ mA}$

$\therefore \quad V_{CE} = V_{CC} - I_C(R_C + R_E) = 12 - 0.93\times(5+1) = \mathbf{6.42\ V}$

29. $V_B = \dfrac{R_2}{R_1 + R_2}\times V_{CC} = \dfrac{100}{200 + 100}\times 15 = 5\ \text{V}$; $V_E \approx V_B = 5\ \text{V}$

$\therefore \quad R_E = \dfrac{V_E}{I_E} = \dfrac{5}{100} = 0.05\ \text{k}\Omega = \mathbf{50\ \Omega}$; $\therefore \quad V_{CE} = V_{CC} - I_C(R_C + R_E) = 15 - 0.1\times(20 + 50) = \mathbf{8\ V}$