Chapter 15

Exercise Solutions

E15.1

(a) Collector Region

$$x_n = \left\{ \frac{2 \in_s (V_{bi} + V_R)}{e} \left(\frac{N_a}{N_d} \right) \left(\frac{1}{N_a + N_d} \right) \right\}^{1/2}$$

Neglecting V_{bi} compared to V_R;

$$x_n = \left\{ \frac{2(11.7)(8.85x10^{-14})(200)}{1.6x10^{-19}} \times \left(\frac{10^{16}}{10^{14}} \right) \left(\frac{1}{10^{16} + 10^{14}} \right) \right\}^{1/2}$$

or

$$\underline{x_n = 50.6\ \mu m}$$

(b) Base Region

$$x_p = \left\{ \frac{2(11.7)(8.85x10^{-14})(200)}{1.6x10^{-19}} \times \left(\frac{10^{14}}{10^{16}} \right) \left(\frac{1}{10^{16} + 10^{14}} \right) \right\}^{1/2}$$

or

$$\underline{x_p = 0.506\ \mu m}$$

E15.2

(a) $V_{CC} = 30\ V$, $V_{CE} = 30 - I_C R_C$

Now, maximum power

$\underline{P_T = 10\ W}$, $P_T = 10 = I_C V_{CE}$

Maximum power at $V_{CE} = \frac{1}{2} V_{CC} = \frac{30}{2} = 15\ V$

Then, maximum power at $I_C = \frac{10}{V_{CE}} = \frac{10}{15} = \frac{2}{3}\ A$

Then,

$$I_C(\max) = 2\left(\frac{2}{3}\right) \Rightarrow \underline{I_C(\max) = 1.33\ A}$$

At the maximum power point,

$$15 = 30 - \left(\frac{2}{3}\right) R_L$$

which yields

$$\underline{R_L = 22.5\ \Omega}$$

(b) $V_{CC} = 15\ V \Rightarrow I_C(\max) = 2\ A$

$V_{CE} = V_{CC} - I_C R_L$

We have

$0 = 15 - (2) R_L \Rightarrow R_L = 7.5\ \Omega$

Maximum power at the center of the load line, or at $V_{CE} = 7.5\ V$, $I_C = 1\ A$

Then

$$P(\max) = (1)(7.5) \Rightarrow \underline{P(\max) = 7.5\ W}$$

E15.3

$V_{CE} = V_{CC} - I_C R_E \Rightarrow V_{CE} = 20 - I_C(0.2)$

so

$0 = 20 - I_C(\max)(0.2) \Rightarrow I_C(\max) = 100\ mA$

Maximum power at the center of the load line, or

$$P(\max) = (0.05)(10) \Rightarrow \underline{P(\max) = 0.5\ W}$$

E15.4

For $V_{DS} = 0$, $I_D(\max) = \frac{24}{20} \Rightarrow$

$$\underline{I_D(\max) = 1.2\ A}$$

For $I_D = 0$, $V_{DS}(\max) = V_{DD} \Rightarrow$

$$\underline{V_{DS}(\max) = 24\ V}$$

Maximum power at the center of the load line, or at $I_D = 0.6\ A$, $V_{DS} = 12\ V$

Then $P(\max) = (0.6)(12) \Rightarrow$

$$\underline{P(\max) = 7.2\ W}$$

E15.5

Power $= I_D V_{DS} = (1)(12) = 12\ W$

(c) Heat sink:

$$T_{snk} = T_{amb} + P \cdot \theta_{snk-amb}$$

or

$$T_{snk} = 25 + (12)(4) \Rightarrow \underline{T_{snk} = 73^\circ C}$$

(b) Case:

$$T_{case} = T_{snk} + P \cdot \theta_{case-snk}$$

or

$$T_{case} = 73 + (12)(1) \Rightarrow \underline{T_{case} = 85^\circ C}$$

(a) Device:

$$T_{dev} = T_{case} + P \cdot \theta_{dev-case}$$

or

$$T_{dev} = 85 + (12)(3) \Rightarrow \underline{T_{dev} = 121^\circ C}$$

E15.6

$$\theta_{dev-case} = \frac{T_{j,\max} - T_{amb}}{P_{D,rated}} = \frac{200 - 25}{50} = 3.5\ ^\circ C/W$$

$$P_D(\max) = \frac{T_{j,\max} - T_{amb}}{\theta_{dev-case} + \theta_{case-snk} + \theta_{snk-amb}}$$

$$= \frac{200 - 25}{3.5 + 0.5 + 2} \Rightarrow$$

$$\underline{P_D(\max) = 29.2\ W}$$

Now

$$T_{case} = T_{amb} + P_D(\max)\left[\theta_{case-snk} + \theta_{snk-amb}\right]$$

$$= 25 + (29.2)(0.5 + 2) \Rightarrow$$

$$\underline{T_{case} = 98^\circ C}$$