ECE3050 Homework Set 2

1. A diode has the parameters $I_S = 10\,\text{fA}$, $n = 2$, and $V_T = 25\,\text{mV}$.
   (a) Calculate r_d for $V_D = 0.6\,\text{V}$.

$$r_d = \frac{nV_T}{I_D + I_S} = \frac{nV_T e^{-V_D/nV_T}}{I_S} = 30.72\,\text{M}\Omega$$

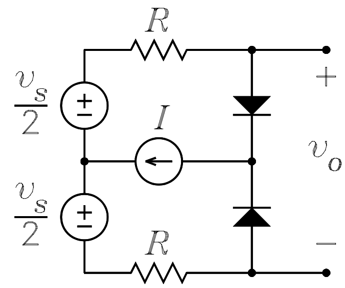
   (b) Calculate r_d for $V_D = 0\,\text{V}$.

$$r_d = \frac{nV_T}{I_S} = 5 \times 10^{12}\,\Omega$$

   (c) At what voltage does r_d exceed $10^{15}\,\Omega$?

$$V_D = nV_T \ln\left(\frac{nV_T}{I_S r_d}\right) = -0.265\,\text{V}$$

2. A diode current-controlled attenuator circuit is shown. It is given that $R = 20\,\text{k}\Omega$. The diode parameters are $n = 2$ and $V_T = 0.025\,\text{V}$.



   (a) Calculate the bias current which will provide a small-signal attenuation of 20 dB, i.e. $v_o/v_s = 0.1$.

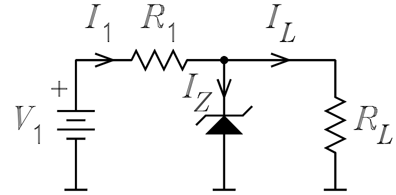
$$I = \frac{2nV_T}{R}\left[\left(\frac{v_o}{v_s}\right)^{-1} - 1\right] = 45\,\mu\text{A}$$

   (b) If the current is halved, what is the new attenuation? (−14.8 dB). (c) If the current is doubled, what is the new attenuation? (−25.6 dB)

3. A diode has the current $I_{D1} = 1\,\text{mA}$ for $V_{D1} = 0.55\,\text{V}$ and $I_{D2} = 2\,\text{mA}$ for $V_{D2} = 0.58\,\text{V}$. If $I_S \ll I_{D1}$, determine the ideality factor or emission coefficient n and the saturation current I_S.

$$\begin{aligned} n &= \frac{V_{D2} - V_{D1}}{V_T \ln(I_{D2}/I_{D1})} = 1.73 \\ I_S &= \frac{I_{D1}}{\exp(V_{D1}/nV_T)} = \frac{I_{D2}}{\exp(V_{D2}/nV_T)} = 3.03\,\text{nA} \end{aligned}$$

4. The diagram shows a zener diode regulator. It is given that $V_1 = 35\,\text{V}$. The diode has the zener voltage $V_Z = 24\,\text{V}$. The load resistance varies between the limits $500\,\Omega \le R_L \le 10\,\text{k}\Omega$.



(a) Calculate R_1 if I_Z is to have a value that is no smaller than 10 mA. Note that I_1 is a constant once R_1 is determined and $I_1 = I_Z + I_L$. Thus the minimum value of I_Z occurs when I_L is a maximum (when R_L is a minimum) because this makes I_Z have the smallest value.

$$R_1 = \frac{35\,\text{V} - 24\,\text{V}}{0.01\,\text{A} + 24\,\text{V}/500\,\Omega} = 190\,\Omega$$

(b) What is the power dissipation in R_1 and the maximum power dissipation in the zener diode? Note that I_1 is a constant and $I_1 = I_Z + I_L$. Thus the maximum dissipation in the zener diode occurs when I_L is its smallest value because this makes I_Z have the largest value.

$$P_1 = \frac{(35\,\text{V} - 24\,\text{V})^2}{190\,\Omega} = 0.637\,\text{W} \qquad P_{Z\,\text{max}} = 24\,\text{V}\left(\frac{35\,\text{V} - 24\,\text{V}}{190\,\Omega} - \frac{24\,\text{V}}{10\,\text{k}\Omega}\right) = 1.33\,\text{W}$$

5. Calculate the values of β and I_S for the transistor shown if $V_{CB} = V_{BE} = 0.7\,\text{V}$, $I_B = 0.2\,\text{mA}$, and $I_E = 10\,\text{mA}$.

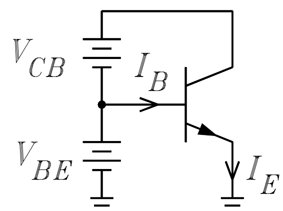
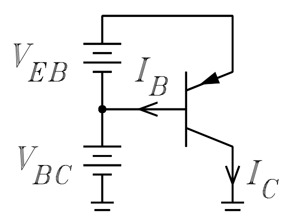


Figure 1:

$$\beta = \frac{10\,\text{mA} - 0.2\,\text{mA}}{0.2\,\text{mA}} = 49 \qquad I_S = \frac{9.8 \times 10^{-3}}{\exp(0.7/0.025)} = 6.78 \times 10^{-15}\,\text{A}$$

6. Calculate the values of β and I_S for the transistor shown if $V_{EB} = V_{BC} = 0.7\,\text{V}$, $I_B = 50\,\mu\text{A}$, and $I_C = 2.5\,\text{mA}$.

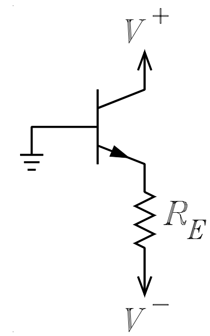


$$\beta = \frac{2.5\,\text{mA}}{50\,\mu\text{A}} = 50 \qquad I_S = \frac{2.5 \times 10^{-3}}{\exp(0.7/0.025)} = 1.73 \times 10^{-15}\,\text{A}$$

7. Calculate the collector, emitter, and base currents if $V^+ = 3.3\,\text{V}$, $V_{EE} = -3.3\,\text{V}$, $V_{BE} = 0.7\,\text{V}$, $R_E = 47\,\text{k}\Omega$, and $\beta = 90$.

$$I_E = \frac{-0.7\,\text{V} - (-3.3\,\text{V})}{47\,\text{k}\Omega} = 55.3\,\mu\text{A} \qquad I_B = \frac{55.3\,\mu\text{A}}{91} = 0.608\,\mu\text{A}$$

$$I_C = I_E - I_B = 54.7\,\mu\text{A}$$



8. An npn transistor is operated in the active mode with a base current of $3\,\mu$A. It is found that $I_C = 240\,\mu$A for $V_{CE} = 5$ V and $I_C = 265\,\mu$A for $V_{CE} = 10$ V. What are the values of β_0 and V_A for this transistor? [$\beta_0 = 71.7$, $V_A = 43.1$ V]

9. A BJT has the parameters $\beta_0 = 75$, $V_A = 100$ V, and $V_{CE} = 10$ V.
(a) Calculate I_C for $r_\pi = 10\,\mathrm{k}\Omega$.

$$I_B = \frac{V_T}{r_\pi} = 2.5\,\mu\mathrm{A} \qquad I_C = \beta_0\left(1 + \frac{V_{CE}}{V_A}\right) I_B = 0.2063\,\mathrm{mA}$$

(b) Calculate the values of g_m and r_0.

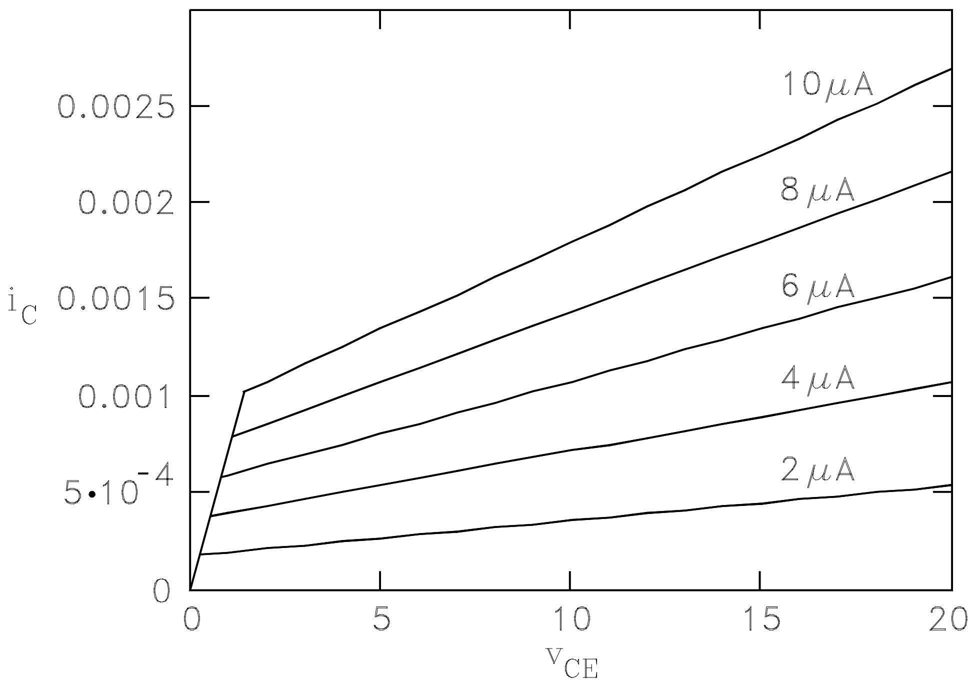
$$g_m = \frac{I_C}{V_T} = \frac{1}{121.2} \qquad r_0 = \frac{V_A + V_{CE}}{I_C} = 533.3\,\mathrm{k}\Omega$$

(c) Calculate α and r_e.

$$\alpha = \frac{\beta}{1+\beta} = \frac{\beta_0\left(1 + \frac{V_{CE}}{V_A}\right)}{1 + \beta_0\left(1 + \frac{V_{CE}}{V_A}\right)} = 0.9880$$

$$r_e = \frac{V_T}{I_E} \overset{or}{=} \frac{V_T}{(1+\beta)\,I_B} \overset{or}{=} \frac{r_\pi}{1 + \beta_0\left(1 + \frac{V_{CE}}{V_A}\right)} = 119.8\,\Omega$$

10. The output characteristics of a BJT are shown. (a) Determine β_0 and V_A. [$\beta_0 = 120$, $V_A = 30$ V] (b) Calculate β at $i_B = 4\,\mu$A and $V_{CE} = 5$ V. [135] (c) Calculate β at $i_B = 8\,\mu$A and $V_{CE} = 15$ V. [225]


10 μA
8 μA
6 μA
4 μA
2 μA
0.0025
0.002
0.0015
0.001
5•10^-4
0
0
5
10
15
20
i_C
v_CE