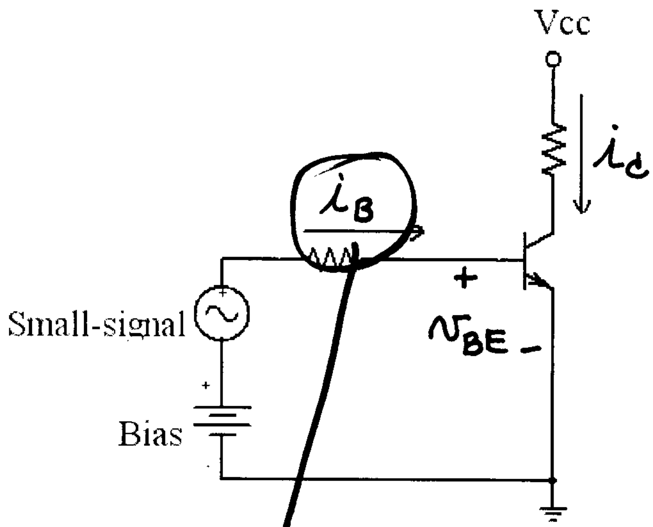
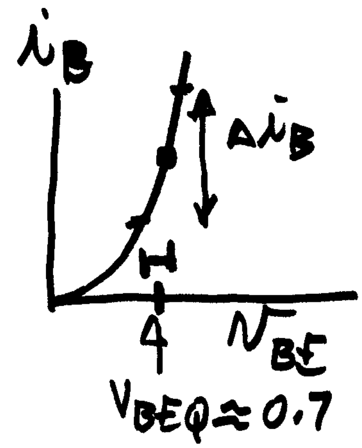
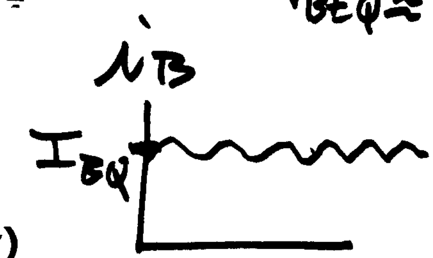
BJT SMALL-SIGNAL MODEL







$$i_B(t) = I_{BQ} + i_b(t)$$

$$i_C = I_S\left[e^{v_{BE}/V_T} - 1\right] \approx I_S\left[e^{v_{BE}/V_T}\right]$$

$$i_B = \frac{i_C}{\beta} = \frac{I_S}{\beta}\, e^{v_{BE}/V_T}$$

TOTAL

$$v_{BE} = V_{BEQ} + v_{be}(t)$$

≈ 0.7

$$I_{BQ} + i_b(t) = \frac{I_S}{\beta}\, e^{[V_{BEQ} + v_{be}(t)]/V_T}$$

$$I_{BQ} + i_b(t) = I_{BQ}\left[e^{v_{be}(t)/V_T}\right]$$

$$I_{BQ} + i_b(t) = \frac{I_S}{\beta}\left[e^{V_{BEQ}/V_T}\right]\left[e^{v_{be}(t)/V_T}\right] = I_{BQ}\, e^{v_{be}(t)/V_T}$$

$$e^x \approx 1 + x \qquad\qquad \text{for } x \ll 1$$

$$I_{BQ} + i_b(t) \approx I_{BQ}\left[1 + \frac{v_{be}(t)}{V_T}\right] = I_{BQ} + I_{BQ}\frac{v_{be}(t)}{V_T}$$

$$i_b(t) = I_{BQ}\left[\frac{v_{be}(t)}{V_T}\right] = v_{be}(t)\left[\frac{I_{BQ}}{V_T}\right]$$

$$\frac{v_{be}(t)}{i_b(t)} = \left[\frac{V_T}{I_{BQ}}\right] = r_\pi$$

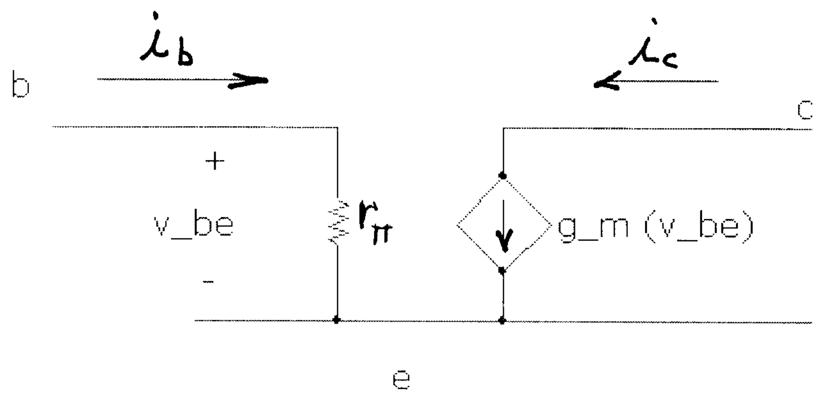
r_π is the small-signal resistance, also called the diffusion resistance. It gives the relationship between small-signal voltage and small-signal current.

$$r_\pi = \left[\frac{V_T}{I_{BQ}}\right] = \left[\frac{\beta V_T}{I_{CQ}}\right]$$

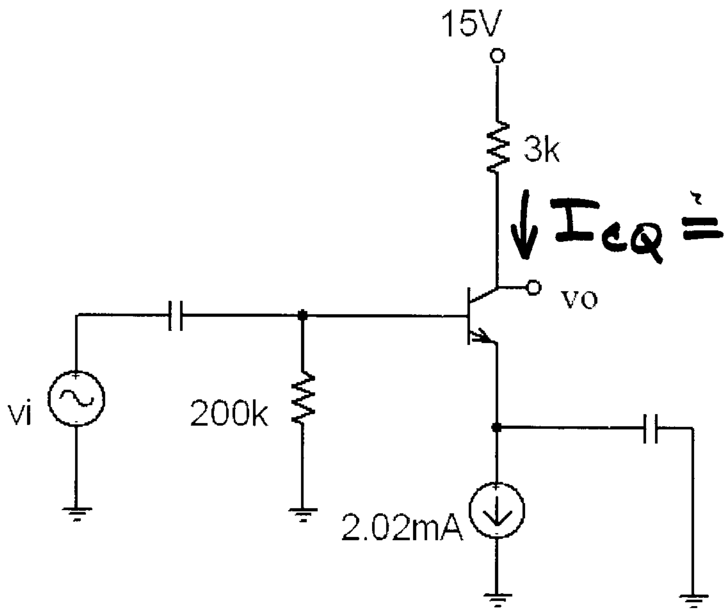
$$i_c(t) = \beta i_b(t) = \beta \frac{v_{be}(t)}{r_\pi}$$

$$g_m = \frac{i_c(t)}{v_{be}(t)} = \frac{\beta}{r_\pi} = \frac{I_{CQ}}{V_T}$$

g_m is the transconductance. It gives the relationship between the small-signal collector current and a small-signal base-emitter voltage.

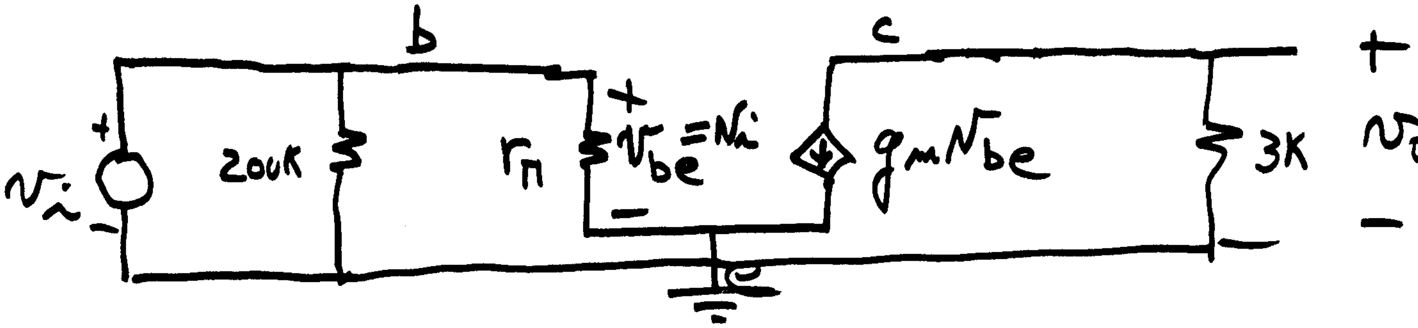


Determine the gain $v_o(t)/v_i(t)$. $\beta = 100$



$$I_{CQ} \doteq \alpha I_{EQ} = \frac{\beta}{1+\beta}(2.02) = 2.0\,mA$$

$$I_{EQ} = 2.02\,mA$$



$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{(100)(26\,mV)}{2\,mA} = 1300\,\Omega = 1.3\,K$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{2\,mA}{26\,mV} = 0.077\,A/V = 77\,mA/V$$

$$v_o = -g_m v_{be}(3K) = -g_m v_i (3K)$$

$$\frac{v_o}{v_i} = -g_m\,3K = (-77)(3) = -231$$