

Exercise 4.21

$$R_B = R_1 || R_2 = 50 \text{ k}\Omega$$

$$V_B = V_{CC} \frac{R_1}{R_1 + R_2} = 10 \text{ V}$$

$$V_B = R_B I_{BQ} + V_{BEQ} + R_E (1 + \beta) I_{BQ}$$

Substituting values, we find  $I_{BQ} = 14.26 \mu\text{A}$ . Then we have

$$I_{CQ} = \beta I_{BQ} = 4.28 \text{ mA}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = 1823 \Omega$$

$$R'_L = \frac{1}{1/R_L + 1/R_E} = 667 \Omega$$

$$A_V = \frac{(1 + \beta) R'_L}{r_\pi + (1 + \beta) R'_L} = 0.991$$

$$Z_{it} = \frac{v_{in}}{i_b} = r_\pi + (1 + \beta) R'_L = 202.5 \text{ k}\Omega$$

$$Z_i = \frac{1}{1/R_B + 1/Z_{it}} = 40.1 \text{ k}\Omega$$

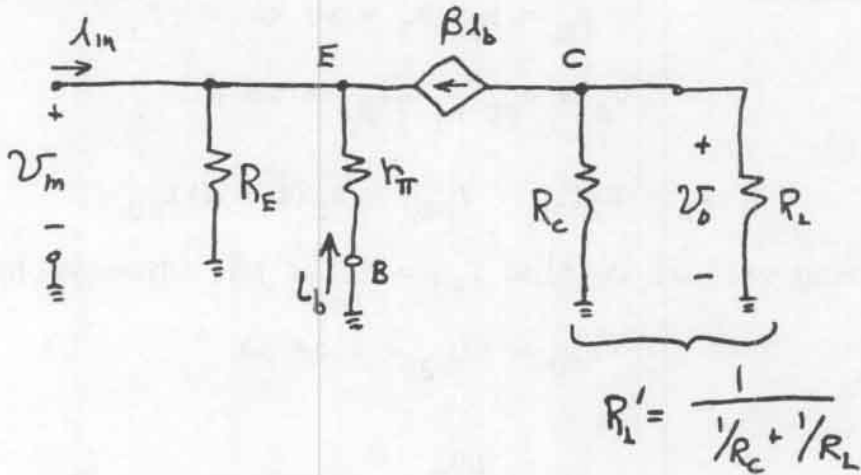
$$R'_S = \frac{1}{1/R_S + 1/R_1 + 1/R_2} = 8.33 \text{ k}\Omega$$

$$Z_o = \frac{v_x}{i_x} = \frac{1}{\frac{1 + \beta}{R'_S + r_\pi} + \frac{1}{R_E}} = 33.2 \Omega$$

$$A_i = A_V \frac{Z_i}{R'_L} = 39.7$$

$$G = A_V A_i = 39.4$$

Exercise 4.22



From the equivalent circuit we can write:  $v_{in} = -r_{\pi}i_b$  and  $v_o = -\beta i_b R'_L$ . Dividing the respective sides of these equations we obtain:

$$A_V = \frac{\beta R'_L}{r_{\pi}}$$

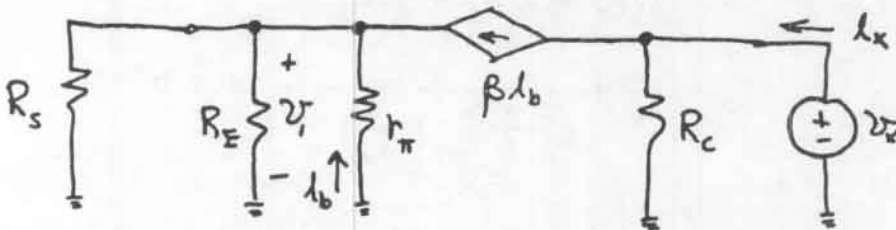
Writing a current equation at the input terminal we have:

$$i_{in} = v_{in}/R_E - (\beta + 1)i_b$$

Then we substitute  $i_b = -v_{in}/r_{\pi}$  and rearrange to obtain:

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{1}{1/R_E + (\beta + 1)/r_{\pi}}$$

The equivalent circuit for determining the output impedance is:



From the circuit we can write:

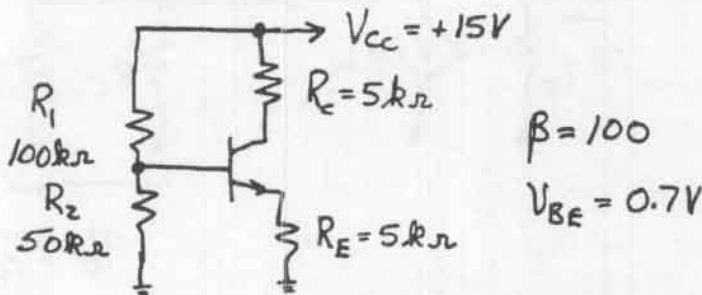
$$v_1/R_S + v_1/R_E = (\beta + 1)i_b \quad \text{and} \quad v_1 = -r_{\pi}i_b$$

Using the second equation to substitute into the first, we obtain  $i_b = 0$ . Thus the controlled source  $\beta i_b$  is an open circuit, and we have

$$R_o = v_x / i_x = R_C$$

### Exercise 4.23

The dc circuit is:



$$R_B = R_1 || R_2 = 33.3 \text{ k}\Omega \quad V_B = V_{CC} R_2 / (R_1 + R_2) = 5 \text{ V}$$

$$I_{BQ} = \frac{V_B - V_{BEQ}}{R_B + (\beta + 1)R_E} = 7.99 \text{ }\mu\text{A} \quad I_{CQ} = \beta I_{BQ} = 0.799 \text{ mA}$$

$$r_\pi = \beta V_T / I_{CQ} = 3254 \text{ }\Omega \quad R'_L = R_C || R_L = 833 \text{ }\Omega$$

$$A_V = \beta R'_L / r_\pi = 25.6 \quad R_i = R_E || [r_\pi / (\beta + 1)] = 32.0 \text{ }\Omega$$

$$R_o = R_C = 5 \text{ k}\Omega \quad A_i = A_V R_i / R_L = 0.819 \quad G = A_V A_i = 21.0$$

### Exercise 4.24

From the equivalent circuit shown in Figure 4.40 in the book we can write:

$$\frac{v_o}{R'_L} + \frac{v_o - v_{in}}{R_B} + \beta i_b = 0$$

Then using  $i_b = v_{in} / r_\pi$  to substitute for  $i_b$  and rearranging the resulting equation we obtain:

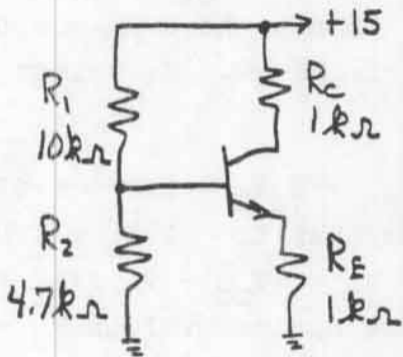
$$A_V = \frac{v_o}{v_{in}} = \frac{R'_L (r_\pi - \beta R_B)}{r_\pi (R'_L + R_B)}$$

Problem 4.45

Dc circuit:

$$\beta = 100$$

$$V_{BEQ} = 0.7 \text{ V}$$



$$V_B = V_{CC}R_2/(R_1 + R_2) = 4.80 \text{ V} \quad R_B = R_1 || R_2 = 3.20 \text{ k}\Omega$$

$$I_{BQ} = \frac{V_B - V_{BEQ}}{R_B + (\beta + 1)R_E} = 0.0393 \text{ mA} \quad I_{CQ} = \beta I_B = 3.93 \text{ mA}$$

$$r_{\pi} = \beta V_T / I_{CQ} = 662 \text{ }\Omega \quad R'_L = R_L || R_C = 500 \text{ }\Omega$$

$$A_v = -\beta R'_L / r_{\pi} = -75.5 \quad A_{vO} = -\beta R_L / r_{\pi} = -151$$

$$Z_{in} = R_1 || R_2 || r_{\pi} = 548 \text{ }\Omega \quad A_i = A_v Z_{in} / R_L = -41.4$$

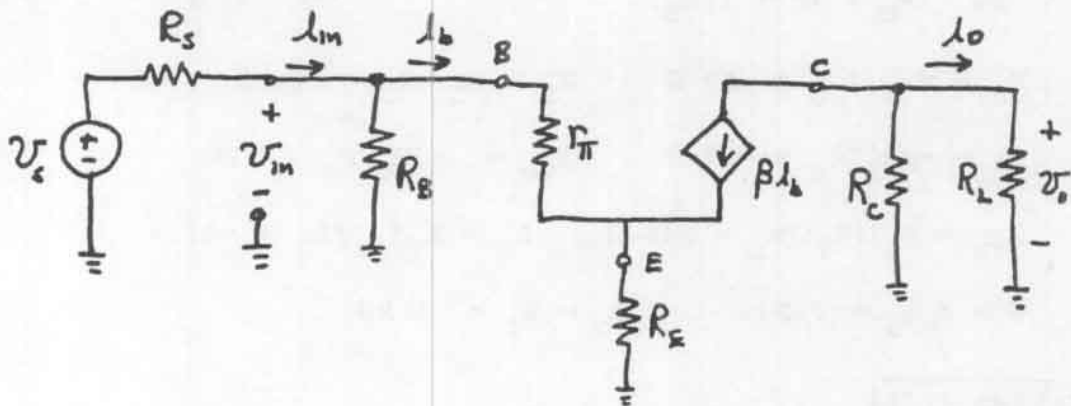
$$G = A_v A_i = 3124 \quad Z_o = R_C = 1 \text{ k}\Omega$$

Problem 4.46

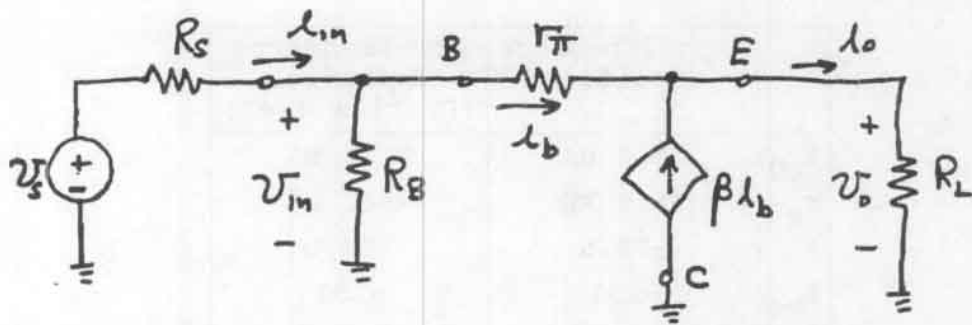
	High-impedance amplifier	Low-impedance amplifier (Problem 4.45)
$I_{CQ}$	39.3 $\mu$ A	3.93 mA
$r_{\pi}$	66.2 k $\Omega$	662 $\Omega$
$A_v$	-75.5	-75.5
$A_{vO}$	-151	-151
$Z_{in}$	54.8 k $\Omega$	548 $\Omega$
$A_i$	-41.4	-41.4
$G$	3124	3124
$Z_o$	100 k $\Omega$	1 k $\Omega$

Problem 4.49

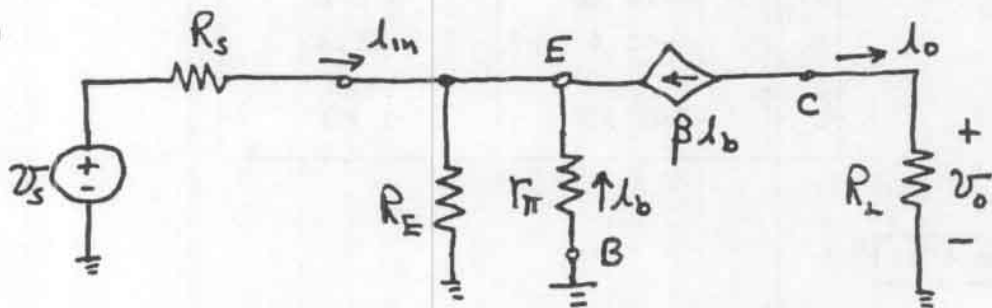
(a)



(b)



(c)

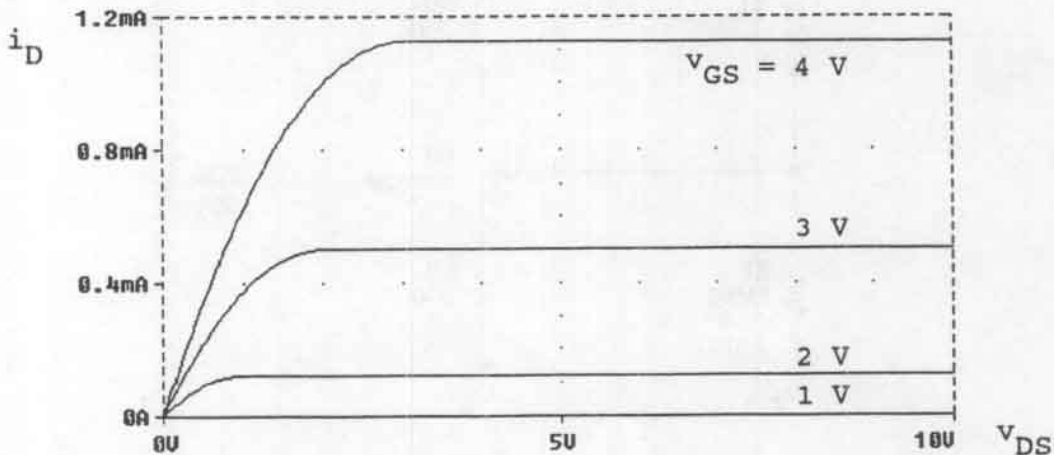


### Exercise 5.1

- (a)  $v_{GS} = 1 \text{ V}$  and  $v_{DS} = 5 \text{ V}$ : Because we have  $v_{GS} < V_{to}$  the FET is in cutoff.
- (b)  $v_{GS} = 3 \text{ V}$  and  $v_{DS} = 0.5 \text{ V}$ : Because  $v_{GS} > V_{to}$  and  $v_{GD} = v_{GS} - v_{DS} = 2.5 > V_{to}$  the FET is in the triode region.
- (c)  $v_{GS} = 3 \text{ V}$  and  $v_{DS} = 6 \text{ V}$ : Because  $v_{GS} > V_{to}$  and  $v_{GD} = v_{GS} - v_{DS} = -3 \text{ V} < V_{to}$  the FET is in the saturation region.
- (d)  $v_{GS} = 5 \text{ V}$  and  $v_{DS} = 6 \text{ V}$ : Because  $v_{GS} > V_{to}$  and  $v_{GD} = v_{GS} - v_{DS} = 1 \text{ V}$  which is less than  $V_{to}$  the FET is in the saturation region.

### Exercise 5.2

The simulation is stored in the file named Exer5\_2. The plots are:



**Problem 5.3**

(a) Saturation because we have  $v_{GS} \cong V_{to}$  and  $v_{DS} \cong v_{GS} - V_{to}$ .

(b) Triode because we have  $v_{DS} < v_{GS} - v_{to}$  and  $v_{GS} \geq v_{to}$ .

(c) Cutoff because we have  $v_{GS} \approx v_{to}$ .