Solution Part 3

1) Show that the input resistance of the amplifier in figure 1 is given by:-

a) $R_i = r_{be} + (1+\beta_o) \times R_E//r_i$

b) and that the voltage gain is:-

$$\frac{v_o}{v_i} = \frac{g_m \times R_E//r_i}{1 + g_m \times R_E//r_i}$$

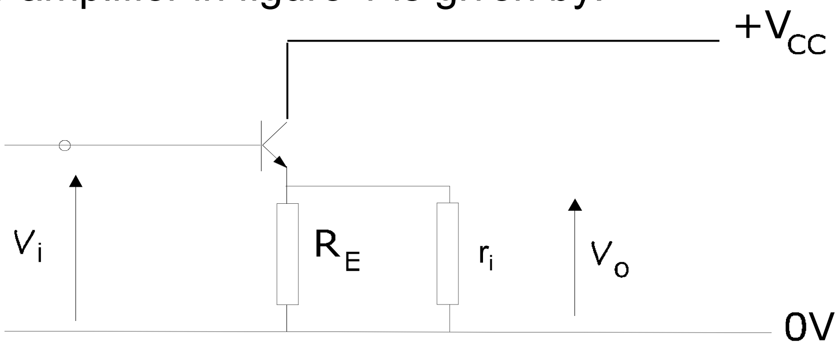
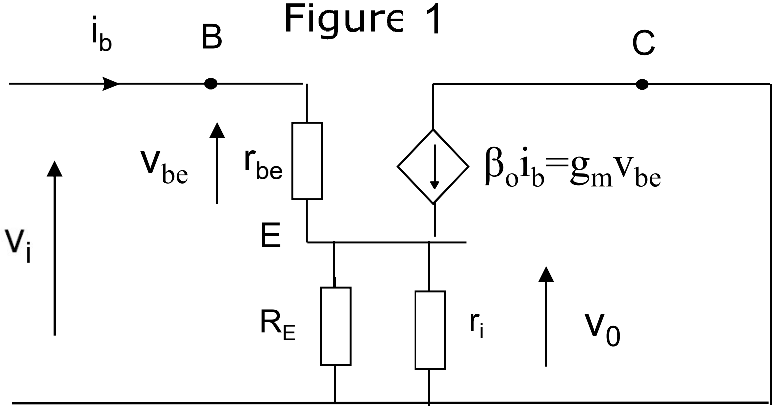


Figure 1



Solution

a) $v_i = v_{be} + v_o$

$$= i_b r_{be} + (1+\beta_o) i_b \times R_E//r_i$$

$$R_i = r_{be} + (1+\beta_o) \times R_E//r_i$$

b) $$\frac{v_o}{v_i} = \frac{i_b(1+\beta_o)\times R_E//r_i}{i_b r_{be} + (1+\beta_o) i_b \times R_E//r_i} \approx \frac{\beta_o \times R_E//r_i}{r_{be} + \beta_o \times R_E//r_i} = \frac{g_m \times R_E//r_i}{1 + g_m \times R_E//r_i}$$

2). The amplifier in figure 2 has one of its inputs grounded. Show that the input resistance for the input signal applied to the remaining input is

$$R_i = r_{be} + (1 + \beta_o) \times R_E//r_e$$

where $r_e = r_{be}/(1 + \beta_o) \approx 1/g_m$

and that the voltage gain is

$$\frac{v_o}{v_i} = \frac{g_m \times R_E//r_e}{1+g_m \times R_E//r_e} \times g_m R_C$$

Show that these reduce to:-

$R_i \approx 2r_{be}$ and $v_o/v_s \approx g_m R_c/2$

and state the necessary approximations.

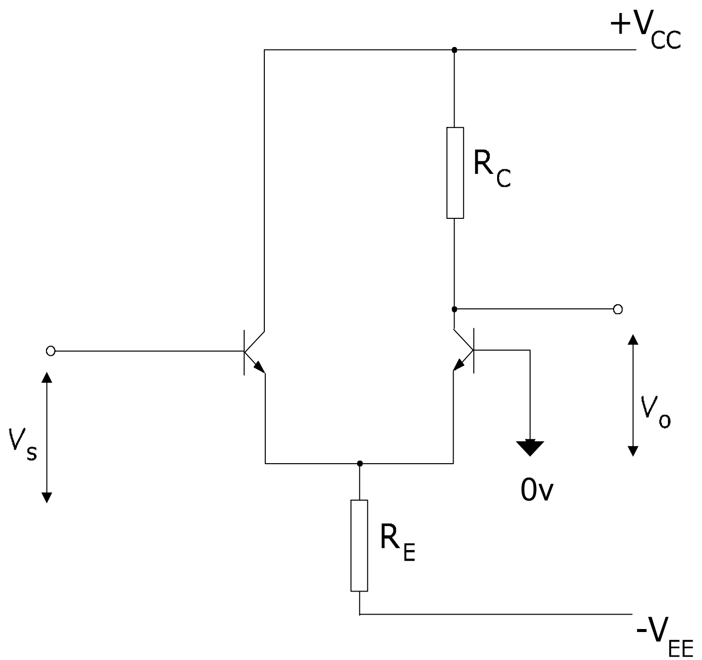
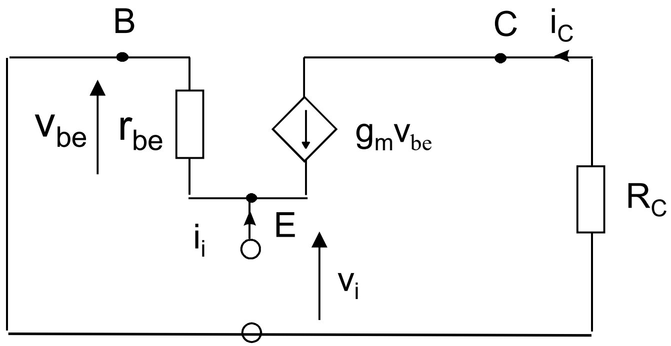
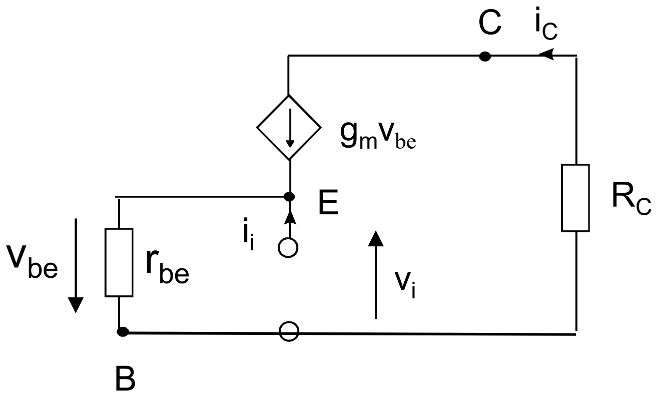


Figure 2

Hint: treat the circuit as a 2-state amplifier: an emitter follower feeding into a common base

2). Consider the second transistor. Replacing the transistor with its equivalent circuit and neglecting r_{ce} gives:





$$i_i + \frac{v_{be}}{r_{be}} + g_m v_{be} = 0 \qquad v_i = -v_{be}$$

$$i_i = \frac{v_i}{r_{be}} + g_m v_i$$

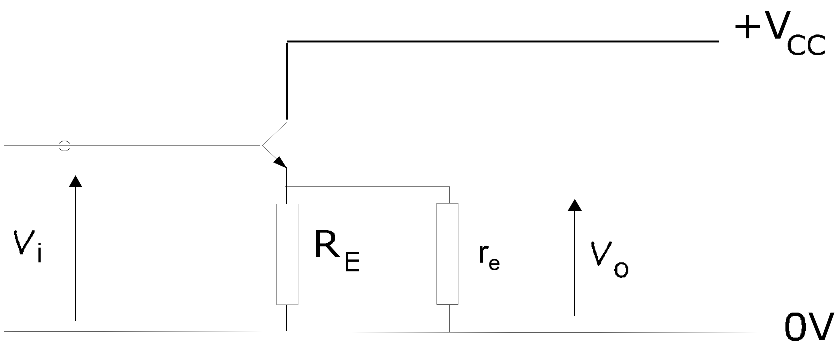
$$\frac{v_i}{i_i} = \frac{r_{be}}{1+g_m r_{be}} = \frac{r_{be}}{1+\beta_o} \approx r_e$$

2). Now connect this as a load on the first transistor

This has already been analysed in Q1, for which

$$R_i = r_{be} + \left(1 + \beta_o\right) \times R_E // r_i$$

where now $r_e = r_i$



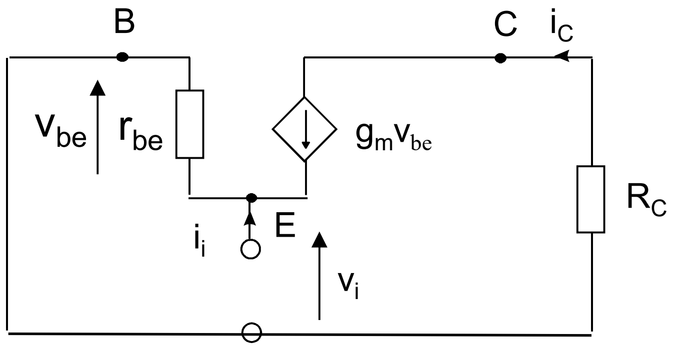
Hence

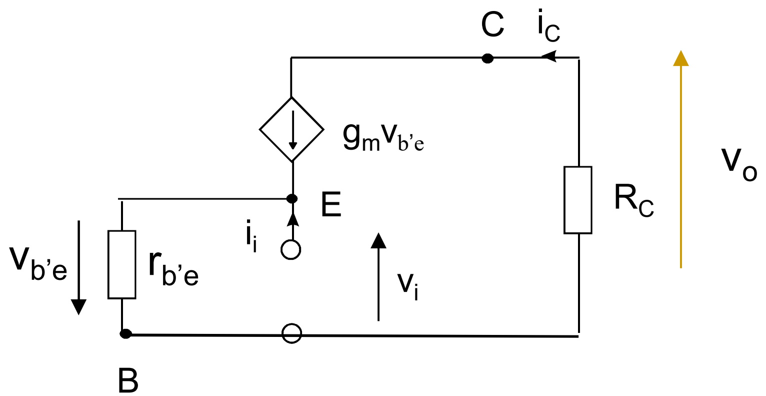
$$R_i = r_{be} + \left(1 + \beta_o\right) \times R_E // r_e$$

Assume $R_E >> r_e$

$$R_i \approx r_{be} + \beta_o g_m \quad = 2r_{be}$$

2). Consider the second transistor. Replacing the transistor with its equivalent circuit and neglecting r_{ce} gives:





$$v_o = g_m v_i R_C$$

$$\frac{v_o}{v_i} = g_m R_C$$

Gain of first stage is ≈ 1/2

$$\frac{v_o}{v_s} \approx \frac{g_m R_C}{2}$$