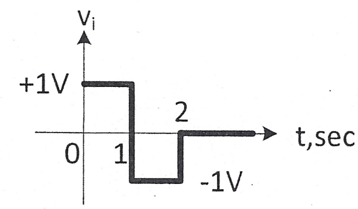
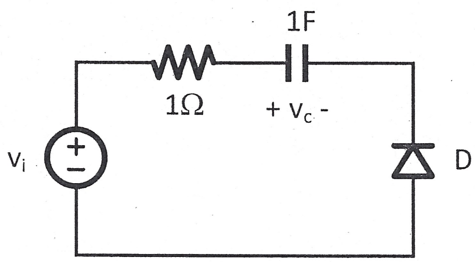
1. The circuit shown below is in zero state at $t = 0$. Calculate and plot the capacitor voltage ($v_c(t)$) for $t \geq 0$ given the input signal shown. The diode is ideal.





$i(t) = c\frac{dv_c(t)}{dt}$

$-1 = i(t)\cdot 1 + v_c(t)$

$-1 = \frac{dv_c(t)}{dt} + v_c(t)$

$e^t v_c(t) = \int -1 e^t$

$e^t v_c(t) = -e^t + c$

$v_c(t) = -1 + ce^{-t}$

$v_c(t) = -1 + ce^{-(t-1)}$

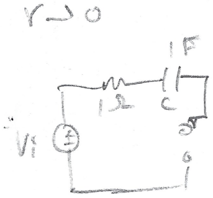
$1 = -1 + c$

$2 = c$

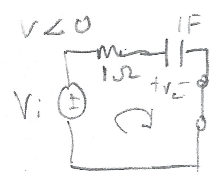
$v_c(t) = 2e^{-(t-1)} - 1$

$i_c(t) = c\frac{dv_c}{dt}$

$v > 0$



$v < 0$



$V_c(t) = 1V$

$V_i = 1\,i(t) + V_c(t)$

$V_i = \frac{C\,dV_c(t)}{dt} + V_c(t)$

$\frac{dV_c(t)}{dt} + V_c(t) = V_i$

$= e^{\int dt}$

$e^t V_c(t) = \int V_i e^t$

$V_i = -1$

$e^t V_c(t) = V_i e^t + c$

$V_c(t) = V_i + ce^{-(t-1)}$

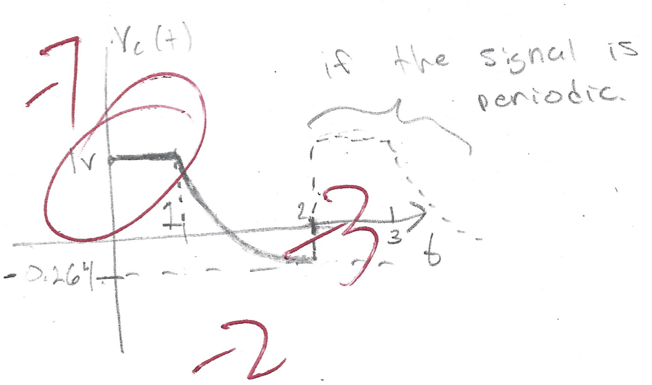
$1 = V_i + C$ $\quad C = 2$

$C = 1 - V_i = 2 \quad (V_i = -1)$

$V_c(t) = -1 + 2e^{-(t-1)}$

$$V_c(t) = 2e^{-(t-1)} - 1$$

$V_c(2) = -0.264$



2. For the circuit below, let $I_{ES} = 1pA$, $V_A = \infty$, $\beta = 100$, $V_{CE,SAT} = 0.2V$, $R_B = 89k\Omega$.

   a. For $R_C = 1k\Omega$, find the exact transistors operating point and the region of operation.

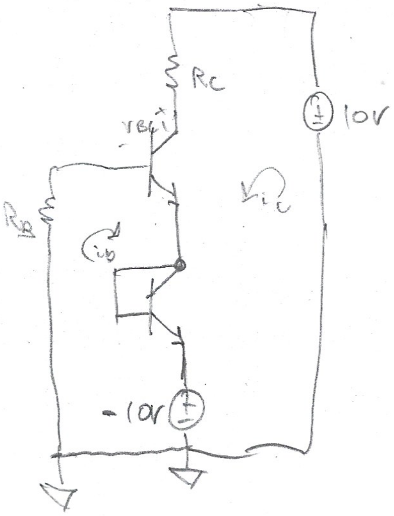
   b. Using $V_{BE,ON} = 0.6V$ approximation, find the maximum value of R_C that puts Q2 on the edge of saturation.

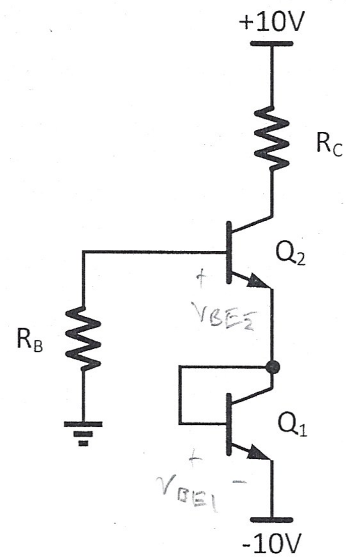
$V_{BC1} =$

$V_{CE} = V_{BE} - V_{BC}$

$V_{BC2} = V_{BE2} - V_{CE2}$

(if they are same transistor then they will have same V_{BE})





$V_{BE1} = V_{BE2}$

$V_{CE1} = V_{BE1}$

$i_{e2} = i_{B1} + i_{E1}$

left loop)

$i_b R_b + V_{BE2} + V_{BE1} + (-10V) = 0$

$10V = i_b R_b + V_{BE2} + V_{BE1}$ (1)

right loop)

$10V = i_c R_c + V_{CE1} + V_{CE2} + (-10V)$

$20V = i_{c1} R_c + V_{CE1} + V_{CE2}$ | $20V = i_{c1} R_c + V_{CE1} + V_{BE2}$ (2)

outer loop)

$10V = R_c i_{c1} + V_{BE1} - V_{CE1} - R_b i_b$ (3)

$10V = i_b R_b + 2V_{BE1}$

$20V = i_{c1} R_c + V_{CE1} + V_{BE2}$

$i_b = \frac{i_c}{\beta}$

$V_{CE1} = 20 - (9.75mA)(1k) - 0.589mA$

$10V = \frac{1}{\beta}(1\times10^{-12}) \exp\left(\frac{V_{BE1}}{V_T}\right) R_b + 2V_{BE1}$

$V_{CE1} = 9.652V$

(Solved using calculator)

$V_{CE1} = V_{BE1} = 0.598V$ | $V_{BE1} = V_{BE2} = 0.598V$

$I_{C1} = (1\times10^{-12}) \exp\left(\frac{0.598}{0.026}\right)$

$I_{C1} = 9.75mA$ | $I_E = 9.75 mA$

3

$I_B = 97.45 \mu A$

$V_{be,on} = 0.6V$

b)

$10V = i_b R_b + V_{BE1} + V_{BE2}$

$10V = i_b R_b + 2V_{BE1}$

$\frac{10V - 2(0.6)}{R_b} = i_b$

$i_b = \frac{8.8}{89000}$

$i_b = 98.88 uA$

$i_c = 9.89 mA$

$i_e = 9.89 mA$

$20V = i_{c1} R_c + V_{CE2} + V_{CE1}$

$V_{BE2} = 0.6V$

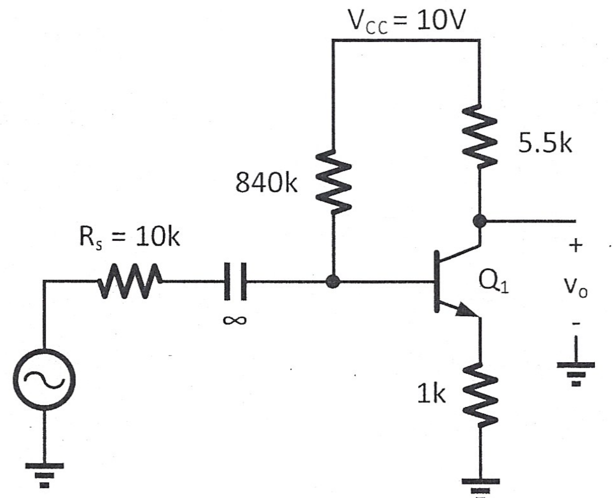
$\frac{20 - 0.6 - 0.2}{i_{c1} = 9.89mA} = R_c$

$R_c = 1.941 k\Omega$

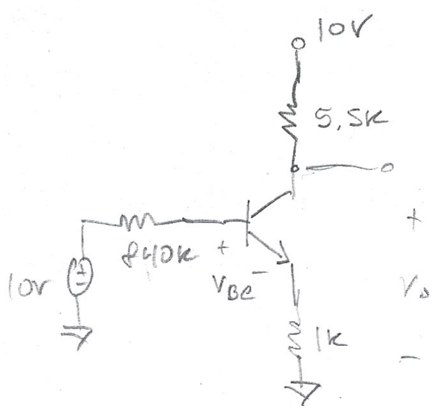
3. In the common-emitter amplifier below, $V_{BE,ON} = 0.6V$, $V_A = \infty$, $\beta = 100$, $V_{CE,SAT} = 0.2V$.

a. Find the DC operating point and the transistor region of operation.

b. Calculate the amplifier small signal voltage gain ($\frac{v_o}{v_s}$).



a)



$10V = 840K\, i_b + V_{BE} + i_e(1K)$

$i_e = i_B + i_c$

$= i_B + \beta i_B$

$i_e = (1+\beta)\, i_B$

$i_b = \frac{10V - 0.6V}{840K + (101)1K} = 9.99\,\mu A$

$i_c = 0.999\,mA \approx 1mA$

$i_e = 1mA$

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region of operation?

$V_{CE} > V_{CE,sat}$

forward active region

$-V_{cc} + V_o + i_c R_c$

$V_o = V_{cc} - i_c R_c$

$V_o = 10V - (1mA)(5.5k)$

$V_o = 4.5V$

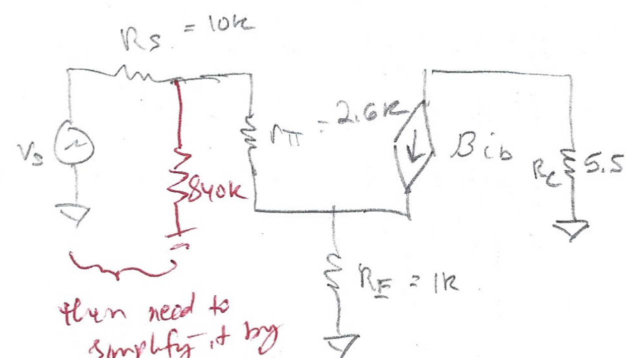
$g_m = \frac{I_c}{V_T}$

$r_\pi = \frac{\beta}{g_m}$

5/5

$r_\pi = 2.6K$

b)



then need to simplify it by thevenin eq ckt.

$V_s = (R_s + r_\pi)\, i_b + R_E\, i_e$

$V_s = (R_s + r_\pi)\, i_b + (101) R_E\, i_b$

15/20

$V_o = -R_c \beta i_b$

$\frac{V_o}{V_s} = -\frac{R_c \beta}{(R_s + r_\pi) + 101 R_E} = \frac{550K}{113.6K}$

$\frac{V_o}{V_s} = -4.84$