ECE115A Midterm Exam Fall 2019

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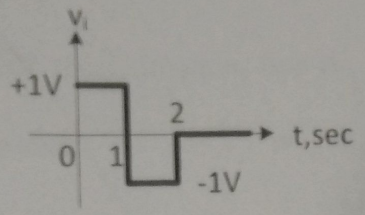
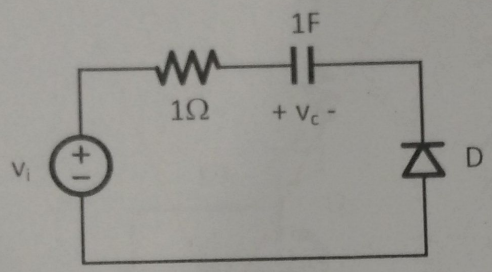
Total of 3 questions, 120 minutes.

P1 (30)	27
P2 (30)	30
P3 (40)	40
Total (100)	97

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.





$\tau = RC = 1$ sec

From $t=0 \to t=1$, no current flows

$t=1 \to t=2$, capacitor charges according to $-(1-e^{-(t-1)})$

$t=2 \to t \to \infty$, no current flows.

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

$$v_c(t) = \begin{cases} 0 & 0 \leq t < 1 \\ e^{-(t-1)} - 1 & 1 \leq t < 2 \\ e^{-1}-1 & 2 \leq t \end{cases}$$

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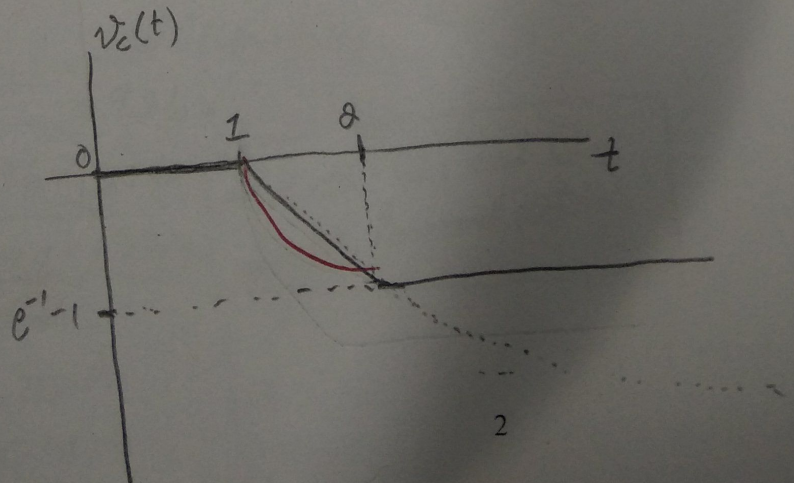
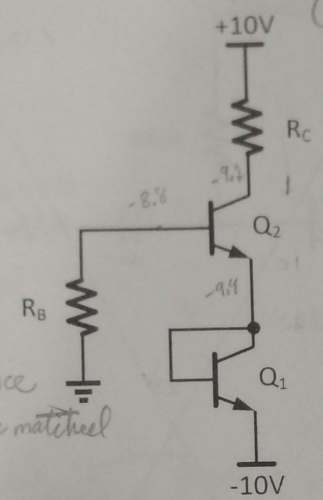


2. For the circuit below, let $I_{ES} = 1pA$, $V_A = \infty$, $\beta = 100$, $V_{CE,SAT} = 0.2V$, $R_B = 89k\Omega$.

   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 Q_2 on the edge of saturation.



(a) Assume Forward Active

$V_{BE} = V_T \ln \frac{I_E}{I_{ES}}$

$V_{BE1} = V_{C1} + 10$

$\frac{0 - V_{B2}}{R_B} = I_{B2} = \frac{1}{\beta+1} I_{E2}$

$V_{B2} = -\frac{R_B}{\beta+1} I_{E2}$

$V_{E2} = V_{C1} = V_{BE1} - 10$ $V_{BE1} = V_{B2}$ since transistors are matched

$\Rightarrow V_{E2} = V_{BE2} - 10$

$V_{BE2} = V_{B2} - V_{E2} = -\frac{R_B}{\beta+1} I_{E2} - V_{BE2} + 10$

$2V_{BE2} = -\frac{R_B}{\beta+1} I_{E2} + 10$

$V_{BE2} = -440.6\, I_{E2} + 5$

$= 4.406 \times 10^{-10} \exp\frac{V_{BE2}}{V_T} + 5$

Solving for V_{BE2}, we find $V_{BE2} \approx 0.597V$

$I_{E2} = 10.25mA$

$I_{C2} = \alpha I_{E2} = 10.14mA$ $I_{B2} = \frac{I_{E2}}{\beta+1} = 0.101mA$

$V_{C2} = 10 - I_C R_C = -1.4V$

$V_{CE2} = V_{C2} - V_{C1} = -1.4V - (-10 + 0.6)$

$= 9.26V$

$V_{CE2} = 9.26V > 0.2$

$V_{BE2} = 0.597V > 0.2$

$\Rightarrow$ Both Q1 and Q2 are forward active

$I_{B1} = I_{B2} = 0.101mA$

$I_{E1} = I_{E2} = 10.25mA$

$\Rightarrow I_{C1} = I_{C2} = 10.14mA$

$V_{CE1} = V_{BE1} \approx 0.597V$

(b) $V_{C2} = -10 + 0.6 = -9.4V$

$V_{B1} = V_{E1} + 0.6 = -9.4 + 0.6 = -8.8V$.

$I_{B1} = \frac{0 - (-8.8)}{R_B} = 98.9\mu A$

$I_{C1} = \beta I_1 = 9.89mA$

$V_{C1} = 10 - I_{C1} R_C$

$V_{CE} = 0.2 = V_{C1} - V_{E1}$

$0.2 = 10 - I_{C1} R_C - (-9.4)$

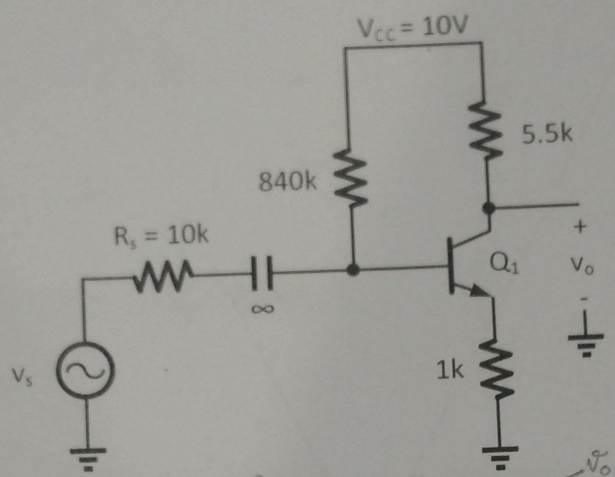
$I_{C1} R_C = 19.2V$

$R_C = 1.94k\Omega$

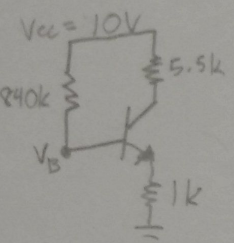
3. In the common-emitter amplifier below, $V_{BE,ON} = 0.6V$, $V_A = \infty$, $\beta = 100$, $V_{CE,SAT} = 0.2V$.

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)



$$\frac{V_B - V_{CC}}{840k} + \left(\frac{V_B - V_{BE\,on}}{1k}\right)\frac{1}{\beta+1} = 0$$

$$\left(\frac{1}{840k} + \frac{1}{(\beta+1)1k}\right)V_B = \frac{10}{840k} + \frac{0.6}{(101)1k}$$

$$1.109\times10^{-5}\,V_B = 1.785\times10^{-5}$$

$$V_B = 1.61V$$

$$\Rightarrow V_E = 1.01V \Rightarrow I_E = \frac{V_E}{1k} = 1.01mA$$

$$I_C = \alpha I_E = 1mA$$

$$I_B = \frac{I_C}{\beta} = 10\mu A$$

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$$V_{CE} = V_{CC} - I_C(5.5k) - V_E$$

$$V_{CE} = 3.49V > 0.2V$$

$$V_{BE} = 0.6V$$

$V_T = 26mV$

$$g_m = \frac{I_C}{V_T} = 38.6mS$$

$$r_\pi = \frac{\beta}{g_m} = 2.59k\Omega$$

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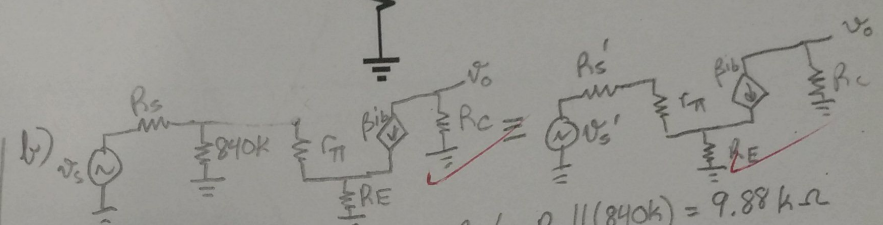
Region of Operation: Forward Active

b)



$$v_s' = v_s\frac{840k}{R_s+840k} = 0.988\,v_s \qquad R_s' = R_s \| (840k) = 9.88k\Omega$$

$$i_b = \frac{v_s'}{R_s' + r_\pi + (\beta+1)R_E} = \frac{v_s'}{113.5k\Omega} = 8.7\times10^{-6}\,v_s$$

$$v_o = -\beta i_b R_C = -\beta R_C(8.7\times10^{-6}\,v_s) = -4.79\,v_s$$

$$\Rightarrow \frac{v_o}{v_s} = -4.79$$

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