1) Calculating α and β relationships

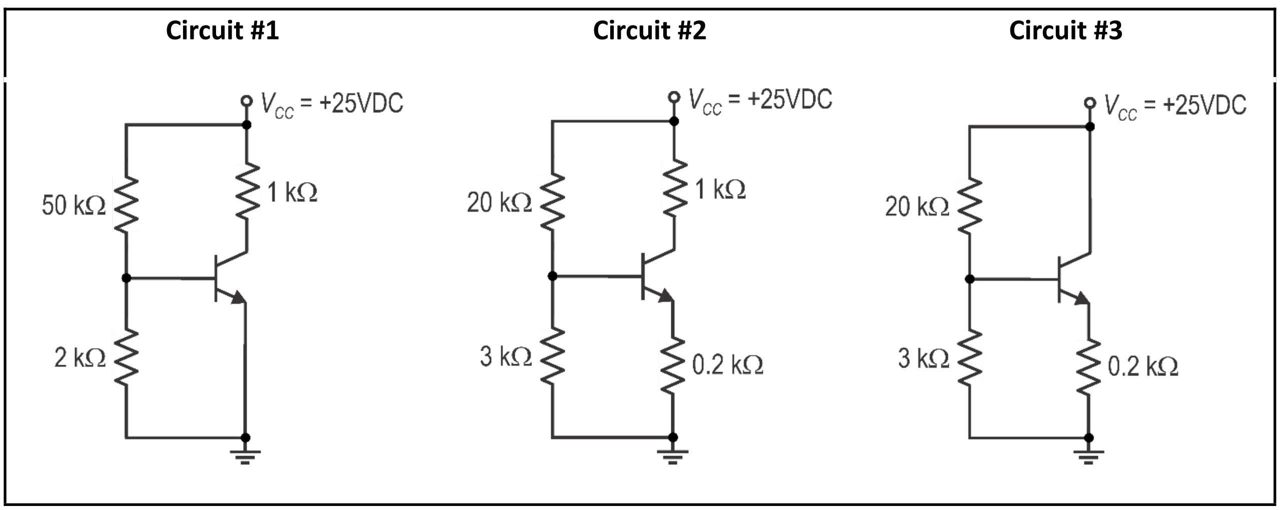
Knowing that $\alpha = \frac{\beta}{1+\beta}$ and $\beta = \frac{\alpha}{1-\alpha}$, fill in the following tables with the missing parameters. Calculate α to four decimal places. (a spreadsheet app, such as Microsoft Excel, could be helpful)

α =	0.98	0.99	0.995	0.996	0.998
β =					

β =	50	75	100	150	200	300
α =						

2) BJT DC Parameters:

For the following three BJT circuits operating at DC, **and referring to Example 6.10 in the textbook**, calculate the associated parameters. Use $\beta = 100$, $V_{BE,ON} = 0.7$ V and $V_{CE,SAT} = 0.3$ V.



a) Calculate I_{BQ}, I_{CQ} and V_{CEQ} for each of the three circuits above. Also state if $V_{CEQ} > V_{CEQ,SAT}$.

	Circuit #1	Circuit #2	Circuit #3
I_{BQ}			
I_{CQ}			
V_{CEQ}			

$V_{CEQ} > V_{CEQ,SAT}$			

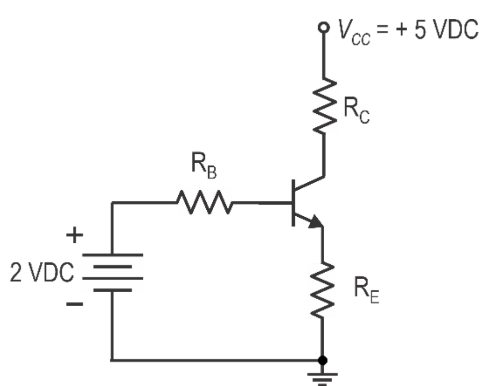
b) For each of these three circuits, calculate the percent change in I_{CQ} when β is changed from 100 to 150 ? Place your results in a table.

$$\% \text{ Change in } I_{CQ} = \left(\frac{I_{CQ,100} - I_{CQ,150}}{I_{CQ,100}} x100\%\right)$$

	Circuit #1	Circuit #2	Circuit #3
% Change in I_{CQ}			

3) BJT circuit at DC:

Use $V_{BE,ON}$ = 0.7 V



a) For I_{CQ} = 0.8 mA and V_{CEQ} = 2v, find R$_C$ and R$_B$ using R$_E$ = 0, β = 80

b) For I_{CQ} = 0.8mA and V_{CEQ} = 2v, find R$_C$ and R$_B$ using R$_E$ = 1K, β = 80

c) Using the resistor values found in (a), change β = 120 and calculate the new I_{CQ} and V_{CEQ}

d) Using the resistor values found in (b), change β = 120 and calculate the new I_{CQ} and V_{CEQ}

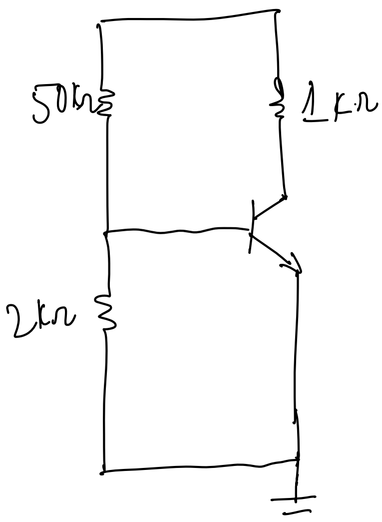
e) Which design, (a) or (b), makes I_{CQ} less sensitive to changes in β? Briefly discuss how you reached that conclusion (in words, a calculation, a table, or other).

1

	A	B
1	Alpha	Beta
2	0.98	49
3	0.99	99
4	0.995	199
5	0.996	249
6	0.998	499

10	Beta	Alpha
11	50	0.9803921569
12	75	0.9868421053
13	100	0.9900990099
14	150	0.9933774834
15	200	0.9950248756
16	300	0.9966777409

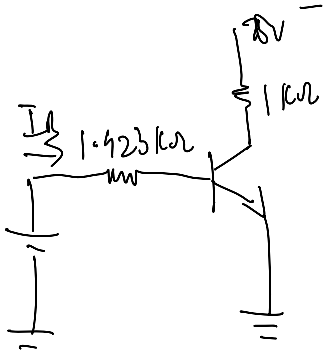
2 a i



$V_{cc} = 25\,V$

$V_{th} = 25 \times \frac{2}{52} = 0.9615\,V$

$R_{th} = \frac{50 \times 2}{52} = 1.923\,k\Omega$



$(I_B)_Q = \frac{0.9615 - 0.7}{1.923} = 0.136\,mA$

$(I_C)_Q = 100 \times 0.136 = 13.6\,mA$

$(V_{CE})_Q = 25 - (1 \times 13.6) = 11.4\,V$

if $\beta = 200$:

$(I_C)_Q = 200 \times 0.136 = 27.2\,mA$

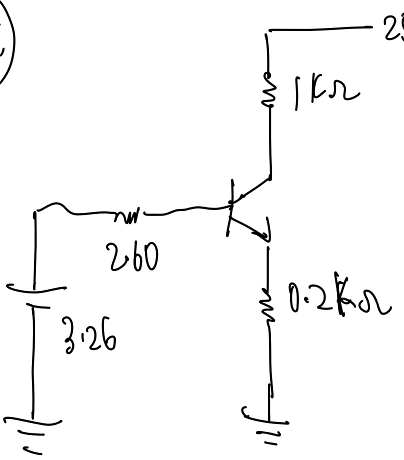
$(V_{CE})_Q = 25 - 27.2 = -2.2\,V$

$(V_{CE})_Q < (V_{CE})_{sat}$ So the transistor is in saturation mode

$(I_C)_Q \neq 27.2\,mA$

$(I_C)_Q = \frac{25 - 0.3}{1\,k\Omega} = 24.3\,mA$

(ii)



$V_{th} = 3.26V$

$R_{th} = 2.60k\Omega$

$$(I_B)_Q = \frac{3.26 - 0.7}{2.60 + (100+1)0.2} = 0.1128\,mA$$

$(I_C)_Q = 11.228mA$

$(V_{CE})_Q = 25 - 11.228 - 2.2456 = 11.5264V$

If $\beta = 200$:

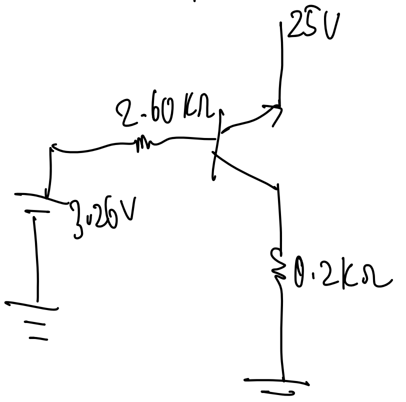
$(I_C)_Q = 22.456mA$

$(V_{CE})_Q = 25 - 22.456 - 4.4912 = -1.9472$

$(V_{CE})_Q < (V_{CE})_{sat}$

$$\therefore (I_C)_Q = \frac{25 - 0.3}{1.2} = 20.5833mA$$

(iii)



$V_{th} = 3.26V$, $R_{th} = 2.60k\Omega$

$$(I_B)_Q = \frac{3.26 - 0.7}{2.60 + (100+1)0.2} = 0.11228mA$$

$(I_C)_Q = 11.228mA$

$(V_{CE})_Q = 25 - (11.228 \times 0.2) = 22.7544V$

If $\beta = 200$:

$(I_C)_Q = 22.456mA$

$(V_{CE})_Q = 25 - (22.456 \times 0.2) = 20.508$

$(V_{CE})_Q > (V_{CE})_{sat}$ Device is in active mode

$\therefore (I_C)_Q = 22.456mA$

	Circuit #1	Circuit #2	Circuit #3
I_{BQ}	0.136 mA	0.11228 mA	0.11228 mA
I_{CQ}	13.6 mA	11.228 mA	11.228 mA
V_{CEQ}	11.4 V	11.526 V	22.754 V
$V_{CEQ} > V_{CEQ,SAT}$	Yes	Yes	Yes

(b)

	Circuit #1	Circuit #2	Circuit #3
% Change in I_{CQ}	−81.60%	−83.320%	−100 %

(8) (a) $I_{CQ} = 0.8mA$, $V_{CEQ} = 2V$, $\beta = 80$, $R_E = 0$

$$-V_{CC} + I_{CQ}(R_C) + V_{CEQ} = 0$$

$$-5 + (0.8 \times 10^{-3}) R_C + 2 = 0$$

$$R_C = \frac{5-2}{0.8 \times 10^{-3}} = 3.75k\Omega$$

<u>KVL at i/p:</u>

$$-2 + I_B R_B + I_E R_E = 0$$

$$-2 + I_B R_B = 0$$

$$R_B = \frac{2}{I_B} = \frac{2}{10\mu A} = 200 k\Omega$$

$$\beta = \frac{I_{CQ}}{I_{BQ}}$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{0.8mA}{80} = 10\mu A$$

(b) $I_{CQ} = 0.8mA$, $V_{CEQ} = 2V$, $\beta = 80$, $R_E = 1K$

$$-V_{CC} + I_{CQ}(R_C) + V_{CEQ} + I_E R_E = 0$$

$$-5 + I_{CQ}(R_C + R_E) + 2 = 0$$

$$I_{CQ}(R_C + R_E) = 3$$

$$R_C + R_E = \frac{3}{0.8mA} = 3.75$$

$$R_C = 3.75 - 1K = 2.75K$$

KVL at i/p:

$$-2 + I_B R_B + I_E R_E = 0$$
$$-2 + I_B R_B + I_B(\beta+1)R_E = 0$$
$$-2 + I_B\left(R_B + R_E(\beta+1)\right) = 0$$
$$I_B\left(R_B + (81)(1k)\right) = 2$$
$$R_B + 81k = \frac{2}{10\mu A}$$

$$I_E = I_C + I_B$$
$$= \beta I_B + I_B = I_B(\beta+1)$$

$$R_B = \frac{2}{10\mu A} - 81K = 1.9\,M\Omega$$

(c) KVL at i/p:

$$-2 + I_B R_B + I_E R_E = 0$$
$$I_B R_B = 2$$
$$I_B = \frac{2}{R_B} = \frac{2}{200k} = \frac{1}{100k} = 10\,\mu A$$
$$I_C = \beta I_B = 120(10\mu A) = 1200\,\mu A$$

KVL at output:

$$-5 + 1200 \times 10^{-6}(3.75) + V_{CEQ} = 0$$
$$V_{CEQ} = 5 - 1200(3.75)10^{-3} = 0.05\,V$$

(d) KVL at i/p:

$$-2 + I_B R_B + I_E R_E = 0$$
$$-2 + I_B R_B + I_B R_E(\beta+1) = 0$$
$$I_B\left(R_B + R_E(\beta+1)\right) = 2$$
$$I_B = \frac{2}{1.91\times10^{6} + 121k} = 0.98\,\mu A$$

$$I_E = I_C + I_B$$
$$= \beta I_B + I_B = I_B(\beta+1)$$

$$I_C = \beta I_B = 120 \times 0.98\mu A = 117.6\,\mu A$$

KVL at o/p :

$$-5 + 117.6 \times 10^{-6}(2.75k) + V_{CEQ} + I_E(1k) = 0$$

$$-5 + 117.6 \times 10^{-6}(2.75) + V_{CEQ} + I_B(1k)(\beta+1) = 0$$

$$-5 + 117.6 \times 10^{-6}(2.75k) + V_{CEQ} + (121)(0.98 \times 10^{-6})(1k) = 0$$

$$V_{CEQ} = 5 - 117.6 \times 10^{-6}(2.75k) - 121 \times 0.98 \times 10^{-6}(1k) = 4.55V$$