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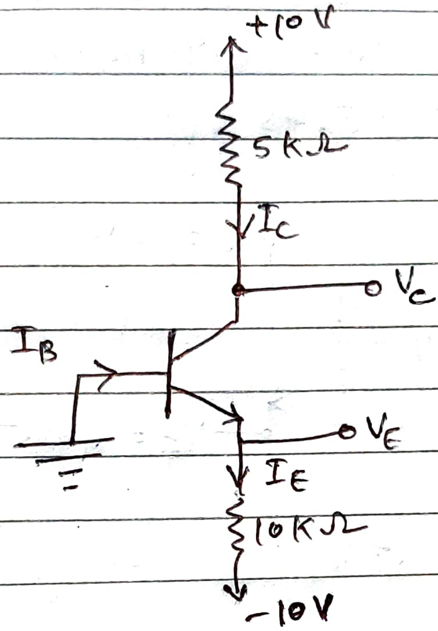
EC100: Assignment 4

Q.1 (3.10 of 4.1) In the circuit shown, the voltage at the emitter was measured and found to be -0.7 V. If $\beta = 50$, find I_E, I_B, I_C and V_C.



The given transistor is npn type, and given $V_E = -0.7$ V.

Assuming, the ~~diode~~ transistor to be operating in active mode.

$$\therefore I_E = \frac{V_E - (-10)}{10\,k\Omega} = \frac{9.3}{10\,k} = 0.93\,mA$$

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

$$\therefore I_B = \frac{0.93\,mA}{51} \quad (\text{as } \beta = 50)$$

$$I_B \approx 0.01823\,mA = 18.23\,\mu A$$

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and $\because$ $I_C = \beta I_B + I_{CO}$ (I_{CO} is negligible)

$\therefore$ $I_C = \beta I_B$

$= 50 \times 18.23 \mu A$

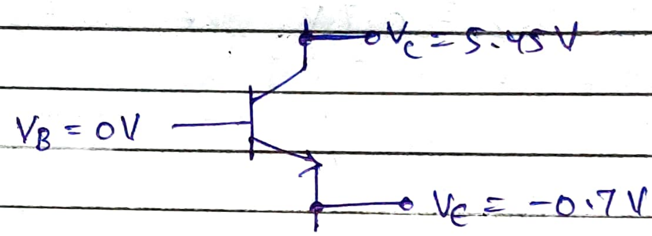
$= 0.91 mA$

and $V_C = 10 - I_C (5 K\Omega)$

$= 10 - (0.91 mA)(5 K\Omega)$

$= 5.45 V$

Now,



Since $V_B - V_E \geq 0.7V$, the emitter junction is forward biased and $V_C - V_B \geq 0.7V$ the collector junction is reverse biased.

Hence, our assumption is correct that the transistor is working in active mode.

Hence, $I_E = 0.93 mA$

$I_B = 18.23 \mu A$

$I_C = 0.91 mA$

$V_C = 5.45 V$

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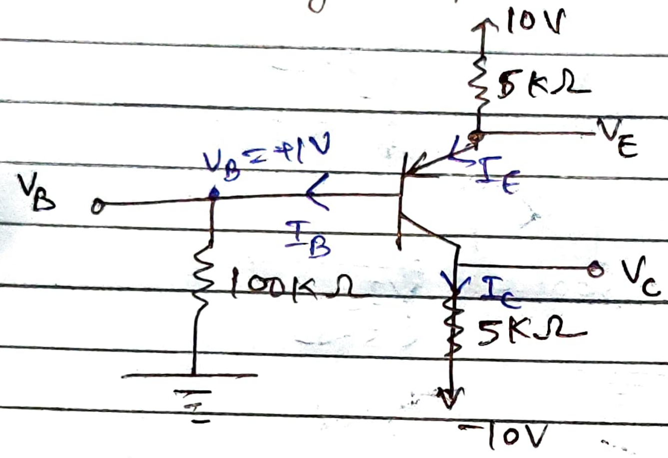
Q.2 (3.11 of 4.1) In the circuit shown, the measurements indicates V_B to be 1 V and V_E to be 1.7 V. What are the values of α and β for this transistor? What voltage V_C do you expect at the collector?



The given transistor is pnp type. Assuming it to be operating in active mode.

Given, $V_B = +1\text{ V}$ and $V_E = +1.7\text{ V}$.

$$\therefore I_B = \frac{V_B - 0}{100K} = \frac{1}{100K} = 0.01\,mA$$

and $$I_E = \frac{10 - 1.7}{5K} = \frac{8.3}{5K} = 1.66\,mA.$$

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

$$\therefore \beta + 1 = \frac{I_E}{I_B} = \frac{1.66\,mA}{0.01\,mA}$$

$$\beta + 1 = 166$$
$$\beta = 165$$

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$\because \quad \alpha = \dfrac{\beta}{\beta+1} = \dfrac{165}{166}$

$\alpha = 0.994$

$\because \quad I_C = \beta I_B + I_{CO}$ (I_{CO} is negligible)

$I_C = 165 \times 0.01 \, mA$

$I_C = 1.65 \, mA$

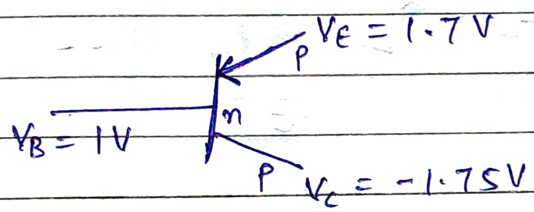
$\therefore \quad V_C = -10 + I_C R_C$

$V_C = -10 + (1.65 \, mA)(5 \, k\Omega)$

$V_C = -10 + 8.25$

$V_C = -1.75 \, V$

Now,



$\because \quad V_E - V_B \geq 0.7V$, emitter junction is forward bias.
and since, $V_B - V_C = 2.75V \geq 0.7V$, the collector junction is reverse biased. Hence, our assumption is correct and $\alpha = 0.994$

$\beta = 165$

and, $V_C = -1.75V$.

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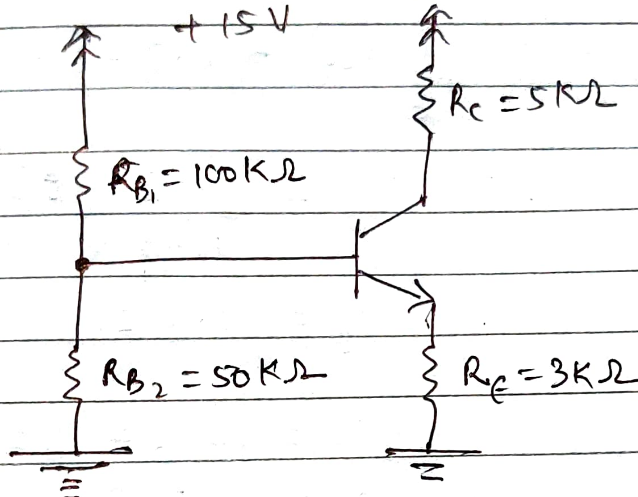
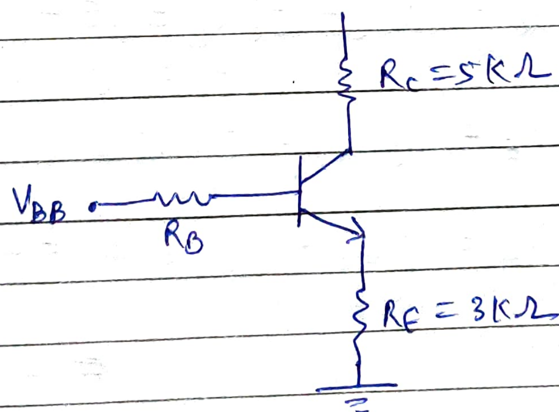
Q.3 (3.27 of 4.1) If the transistor in the circuit is replaced with another having $\beta = 50$ ($\beta = 100$ before), find new value of I_C, and express the change in I_C as percentage



The circuit can be redrawn as



$$V_{BB} = V_{cc} \times \frac{50\,K}{150\,K}$$ (voltage divider)

$$V_{BB} = 15 \times \frac{50}{150} = 5V$$

and $R_B = R_{B1} \parallel R_{B2} = 100K \parallel 50K$
$$= \frac{100}{3} K\Omega$$

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If $\beta = 100$ and assuming that transistor is in active mode:

$$5 - I_B R_B - V_{BE} - I_E R_E = 0$$

$$5 - I_B\left(\frac{100\,k\Omega}{3}\right) - 0.7 - (\beta+1) I_B (3k\Omega) = 0$$

$$I_B = \frac{4.3 \times 3}{1009 \times 1000}$$

$$I_B = 0.0128\ mA$$

$$\therefore\ I_C = \beta I_B = 1.28\ mA$$

$$I_E = 1.2928\ mA$$

$$V_C = V_{CC} - I_C R_C = 15 - (1.28\,mA)(5k\Omega)$$
$$= 8.6\ V$$

$$V_E = I_E R_E = 3.878\ V$$

$$V_B = V_{BB} - I_B R_B = 5 - (0.0128\,mA)\left(\frac{100\,k\Omega}{3}\right)$$
$$= 5 - 0.427$$
$$= 4.573\ V$$

n $V_C = 8.6\ V$

$V_B = 4.573$ → P

n $V_E = 3.878\ V$

Since, the emitter junction is in FB and collector junction is in RB, our assumption is correct,

and I_C (at $\beta = 100$) $= 1.28\ mA$

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If $\beta = 50$, and assuming that transistor is in active mode

$$I_B = \frac{4.3 \times 3}{559 \times 1000}$$

$$I_B = 0.0230 \text{ mA}$$

$$\therefore I_C = 50 \times 0.023 = 1.15 \text{ mA}$$

$$I_E = 1.173 \text{ mA}$$

$$V_C = V_{CC} - I_C R_C = 15 - (1.15 \text{ mA})(5 \text{ k}\Omega)$$

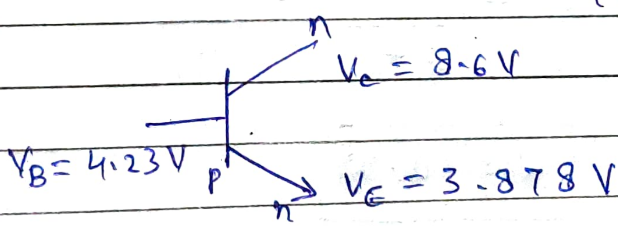
$$V_C = 9.25 \text{ V}$$

$$V_E = I_E R_E = 3.519 \text{ V}$$

$$V_B = V_{BB} - I_B R_B = 5 - (0.023 \text{ mA})\left(\frac{100 \text{ k}\Omega}{3}\right)$$

$$= 5 - 0.77$$

$$= 4.23 \text{ V}$$



Since, the emitter junction is in FB and collector junction is in RB, our assumption is correct. and,

$$I_C \text{ (at } \beta = 50) = 1.15 \text{ mA}.$$

$$\% \text{ change in } I_C = \frac{1.15 - 1.28}{1.28} \times (100\%)$$

$$\approx -10\%$$

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Q 4 (8.5 ex of 4.2) The collector and base current are measured at $I_C = 5mA$, $I_B = 50\mu A$, and $I_{CBO} = 1\mu A$.
(i) Determine α, β and I_E.
(ii) Determine new level of I_B required to produce $I_C = 10mA$

$I_B = 50\mu A$, $I_C = 5mA$, $I_{CBO} = 1\mu A$

(i) $\beta = \frac{I_C}{I_B}$

$= \frac{5 \times 10^{-3}}{50 \times 10^{-6}} = 100$

$\boxed{\beta = 100}$

$\because \alpha = \frac{\beta}{\beta+1} = \frac{100}{101}$

$\boxed{\alpha = 0.99}$

$\because I_E = I_B + I_C$

$I_E = 5.05 \text{ mA}$

(ii) $\because I_C = \beta I_B + I_{CBO}$

$10 \text{ mA} = 100(I_B) + 1\mu A$

$\therefore I_B = \frac{(10 - 0.001)}{100} \text{ mA}$

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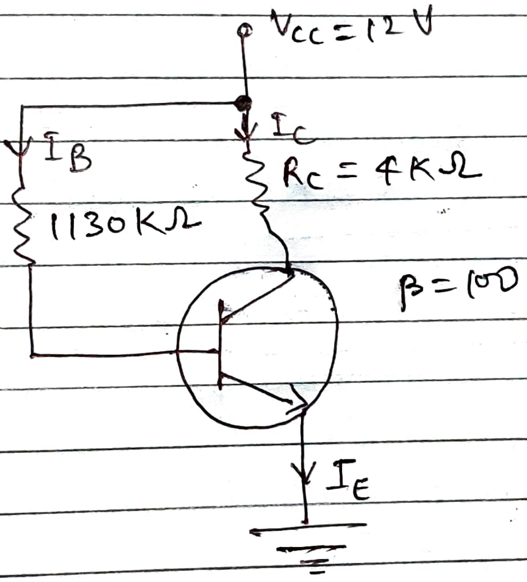
$I_B = 0.0999\ mA$

$\boxed{I_B = 99.9\ \mu A}$

Q5 (45 of 4.2) Figure shows the circuit of fixed bias using a silicon transistor with $\beta = 100$. Determine (i) base current, (ii) collector current (iii) ~~operating point~~ V_C, V_B and V_{CB} (iv) operating point (v) stability factor S.



The transistor is npn. Assuming it to be operating in active mode.

$\because \quad V_B - V_{BE} = 0$

$\therefore \quad V_B = 0.7V$

$\because \quad I_B = \dfrac{V_{CC} - V_B}{1130K\Omega} = \dfrac{12 - 0.7}{1130K\Omega}$

$I_B = 0.01\ mA$

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$\because I_C = \beta I_B + I_{CO}$ (I_{CO} is negligible)

$\therefore I_C = 100 \times 0.01\ mA$
$= 1 mA$

$\because I_E = I_B + I_C = 1.01\ mA$

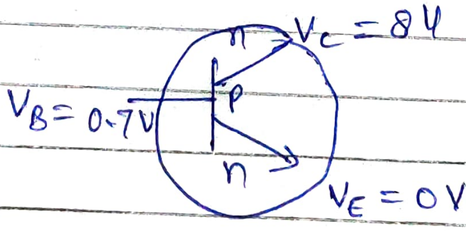
$V_C = V_{CC} - I_C R_C$

$= 12 - (1 mA)(4 k\Omega)$
$= 8 V$

(i) $\boxed{I_B = 10\ \mu A}$

(ii) $\boxed{I_C = 1\ mA}$

(iii) $\boxed{\begin{array}{l} V_C = 8V \\ V_B = 0.7V \\ V_{CB} = 7.3V \end{array}}$



Clearly, emitter junction is FB and base-collector junction is RB. Hence, our assumption is correct.

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(iv) Operating point is (V_C, I_C)

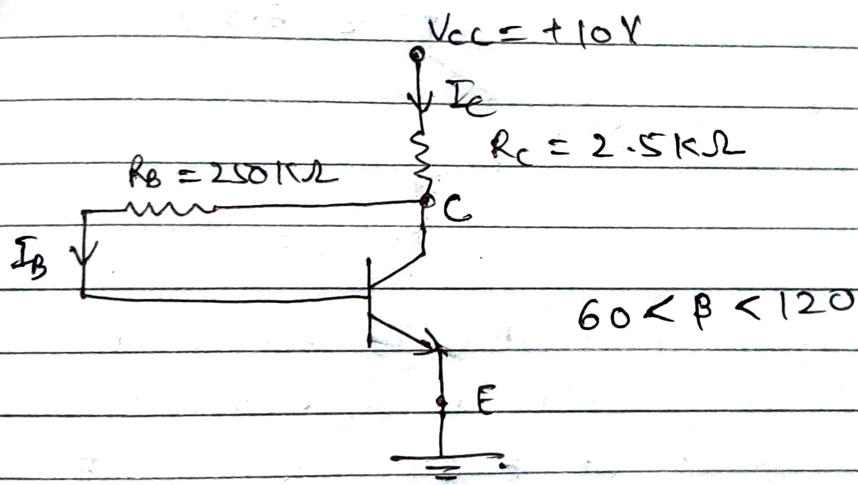
$\therefore$ operating point is (8V, 1mA)

(v) Stability factor $S \approx \beta + 1$

$$\boxed{S = 100 + 1 = 101}$$

(Ex 11.27 of 4.2)

Q.6. Calculate the maximum and minimum collector current in the circuit



Assuming the transistor to be operating in active region:

Applying KVL,

$$V_{CC} - I_C R_C - I_B R_B - V_{BE} = 0$$

$$I_C R_C + I_B R_B = V_{CC} - V_{BE}$$

$$\beta R_C I_B + I_B R_B = V_{CC} - V_{BE} \quad (\because I_C = \beta I_B)$$

$$I_B = \frac{V_{CC} - V_{BE}}{\beta R_C + R_B}$$

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If $\beta = 60$

$$I_B(\text{at } \beta = 60) = \frac{10 - 0.7}{\{(60 \times 2.5) + 250\}K}$$

$$= \frac{9.3}{400K}$$

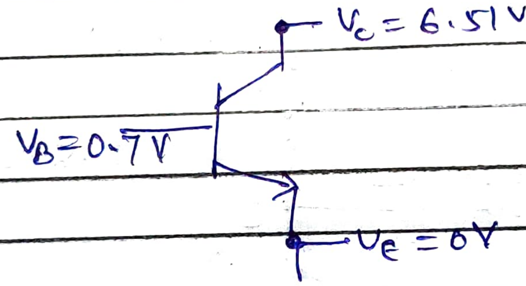
$$I_B(\text{at } \beta = 60) = 0.02325 mA$$

$$\therefore I_C(\text{at } \beta = 60) = 1.395\ mA$$

$$\therefore V_C(\text{at } \beta = 60) = 10 - (1.395 mA)(2.5 K\Omega)$$

$$= 6.51\ V$$

$\therefore$



Clearly, the emitter junction is (FB) and collector junction is RB. Hence, our assumption is correct at $\beta = 60$ and $I_C = 1.395\ mA$

If $\beta = 180$

$$I_B(\text{at } \beta = 180) = \frac{10 - 0.7}{((180 \times 2.5) + 250)K}$$

$$= \frac{9.3}{700K}$$

$$= 0.0133\ mA$$

$$\therefore I_C(\text{at } \beta = 180) = 2.39\ mA$$

$$\therefore V_C(\text{at } \beta = 180) = 4.02\ V$$

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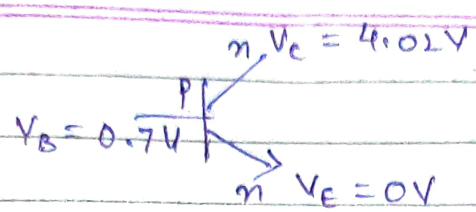
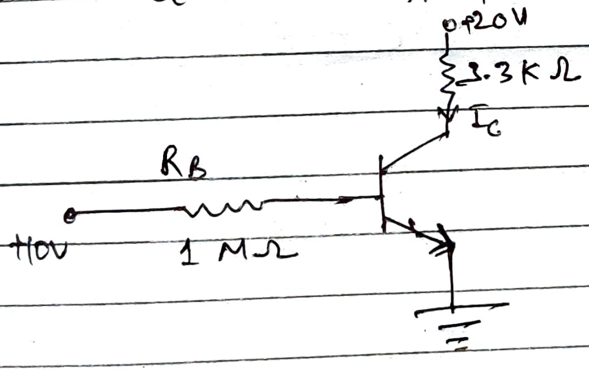
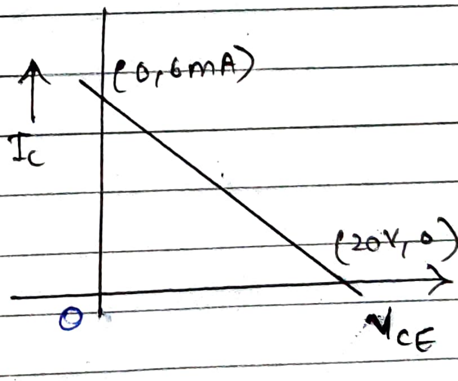


Clearly, emitter junction is (FB) and collector junction is (RB). Our assumption is correct.

Hence, the minimum and maximum value of I_C are 1.395 mA and 2.39 mA.

Q.7 (Q.15 of 4.2) Draw the load line for the following figure. What is I_C at saturation point? Find V_{CE} at cutoff point.





When $V_{CE} = 0$,

$$I_C = \frac{20 - 0}{(3.3 K)} \approx 6.06 \text{ mA}$$

When $I_C = 0$, $V_{CE} = V_{CE} = 20V$

Hence, load line is given in the graph.

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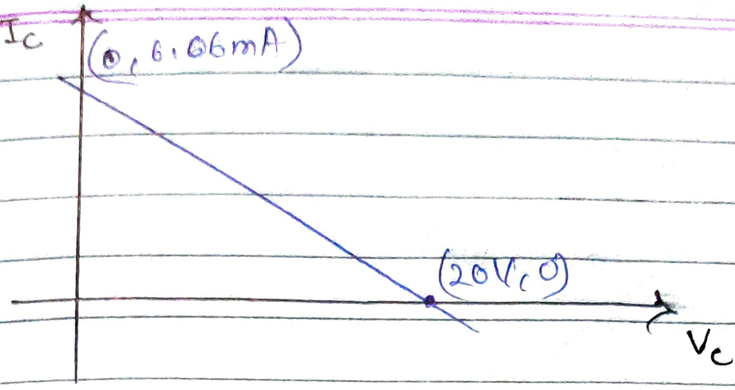
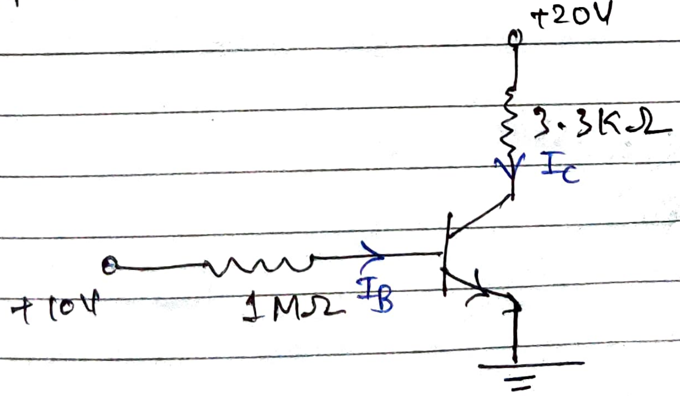


Hence, at saturation point, i.e. $V_c = 0$, current $I_c = 6.06\, mA$.

and, at cutoff point, ie. at $I_c = 0$, the voltage V_{CE},

$\because \quad I_c = 0, \quad V_{CE} = V_{CC} = 20V$

Q.8 (7-6 of 4.1) If the collector supply voltage is increased to 25 V in the figure, what happens to the load line?



From the given circuit,
When $I_c = 0$, $V_c = V_{CC} = 20\, V$

and when $V_c = 0$, $I_c = \dfrac{20 - 0}{(3.3 K\Omega)} = 6.06\, mA$

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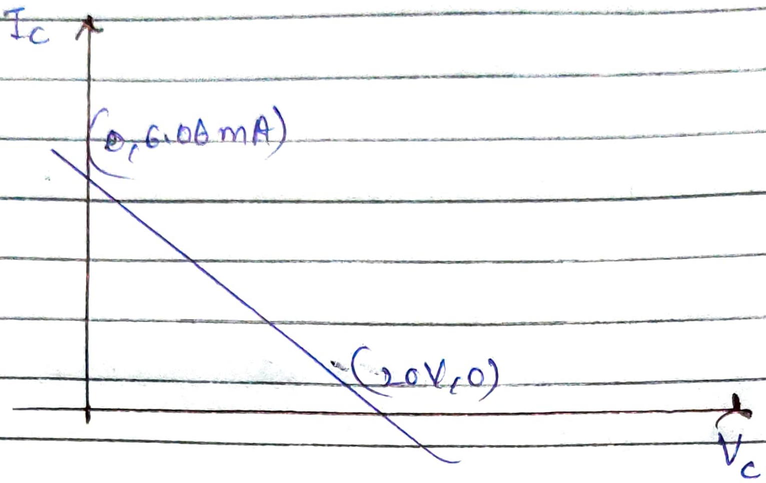
Hence, the load line is

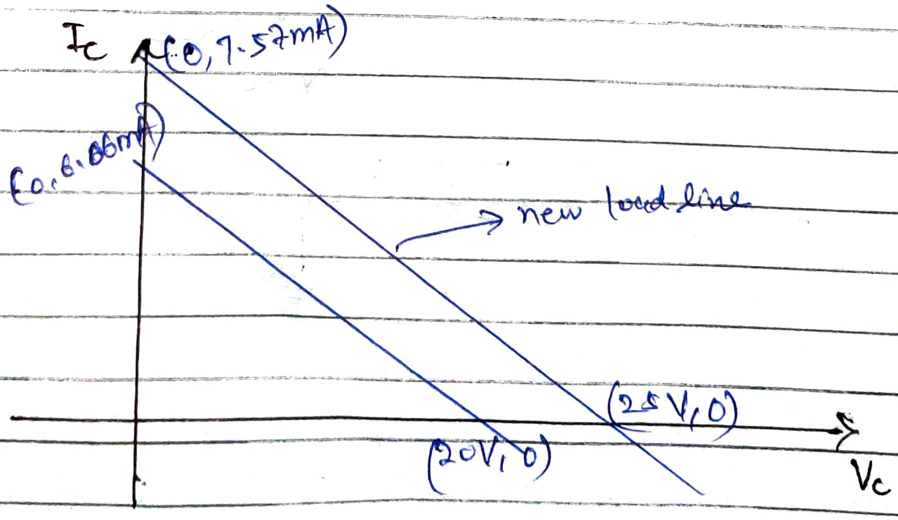


When collector supply voltage is increased to 25 V, i.e. $V_{CC} = 25\,V$, in the circuit,

When $I_C = 0$, $V_C = V_{CC} = 25\,V$.

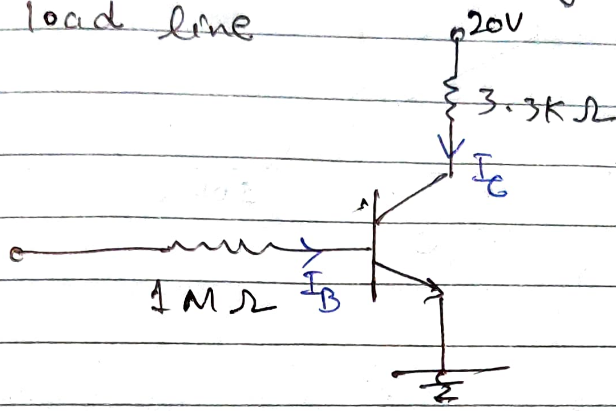
When $V_C = 0$, $I_C = \dfrac{25 - 0}{(3.3\,K\Omega)} = 7.57\,mA$

therefore, the new load line is



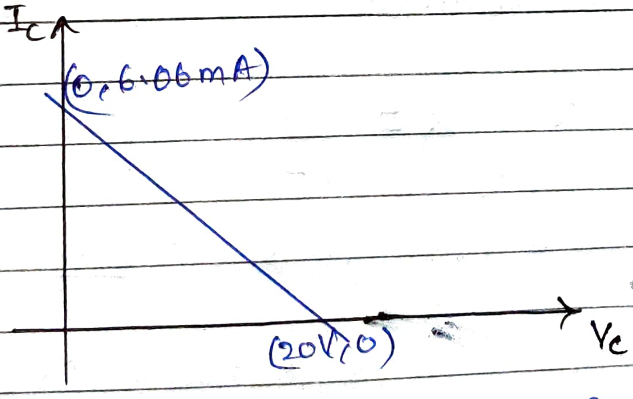
Hence, the slope of load line remains same but its intercept changes.

Q.9 (7-5 of 4.1) If the collector resistance is increased to 4.7 KΩ in Fig. what happens to the load line



From the given circuit,
when $I_c = 0$, $V_c = V_{cc} = 20V$
and when $V_c = 0$, $I_c = \frac{20-0}{(3.3K\Omega)} = 6.06mA$

therefore the load line is,



Now, if the collector resistance R_c is changed to 4.7 KΩ.

when $I_c = 0$, $V_c = V_{cc} = 20V$
and when $V_c = 0$, $I_c = \frac{20-0}{(4.7K)} = 4.25mA$

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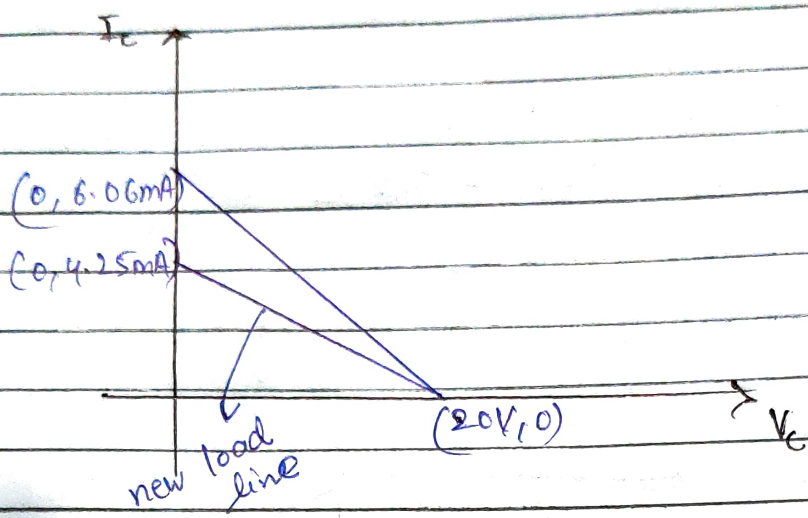
therefore, the new load line is



the slope of the load line is changed and its intercept on I_c axis is reduced.

Q.10 (3-2 of 4-1) Transistors of a certain type are specified to have β values in the range 50 to 150. Find the range of their α values.

$$\because \quad \alpha = \frac{\beta}{\beta+1}$$

$$\alpha\,(\text{when } \beta = 50) = \frac{50}{51}$$

$$\alpha\,(\text{at } \beta = 50) = 0.9804$$

$$\alpha\,(\text{at } \beta = 150) = \frac{150}{151}$$

$$= 0.9934$$

$\therefore$ Range of α is from 0.9804 to 0.9934.

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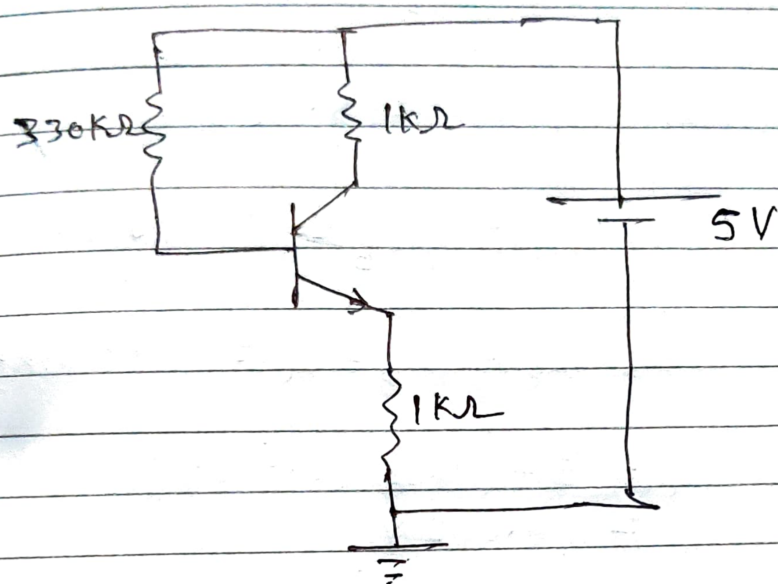
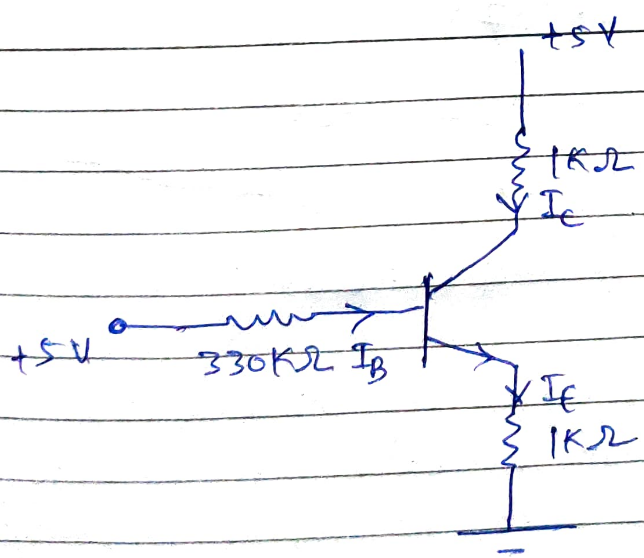
Q.11 (1 of 4-2) In the circuit, the transistor has $\beta = 100$, and its I_{CO} is negligible. Determine the transistor currents.



Assuming the given npn transistor to be operating in active mode. The circuit can be drawn as



$$\therefore \quad (5V) - (330k\Omega)I_B - V_{BE} - (1k\Omega)I_E = 0$$

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$$(330 k\Omega) I_B + (101 k\Omega) I_B = 5 - 0.7 \quad \{\because I_E = (\beta+1) I_B\}$$

$$\therefore I_B = \frac{4.3}{431 k\Omega}$$

$$I_B = 0.00998 mA$$
$$= 9.98 \mu A$$

$$\therefore I_C = \beta I_B = 0.998 mA$$

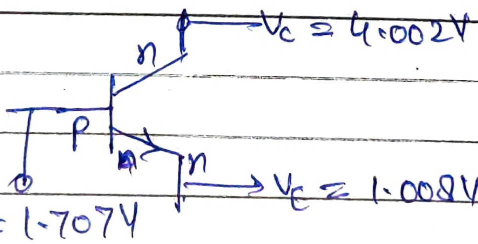
and $I_E = I_B + I_C = 1.008 mA$

$$\therefore V_C = 5 - (1 k\Omega)(0.998 mA)$$
$$= 4.002 V$$

and $V_E = I_E R_E = 1.008 V$

and $V_B = 5 - (330K)(0.00998 mA)$
$= 1.707 V$

Now,



Clearly, emitter junction is forward biased and ~~base~~ collector junction is reverse biased. Hence, our assumption is correct.

and
$$I_B = 9.98 \mu A$$
$$I_C = 0.998 mA$$
$$I_E = 1.008 mA$$

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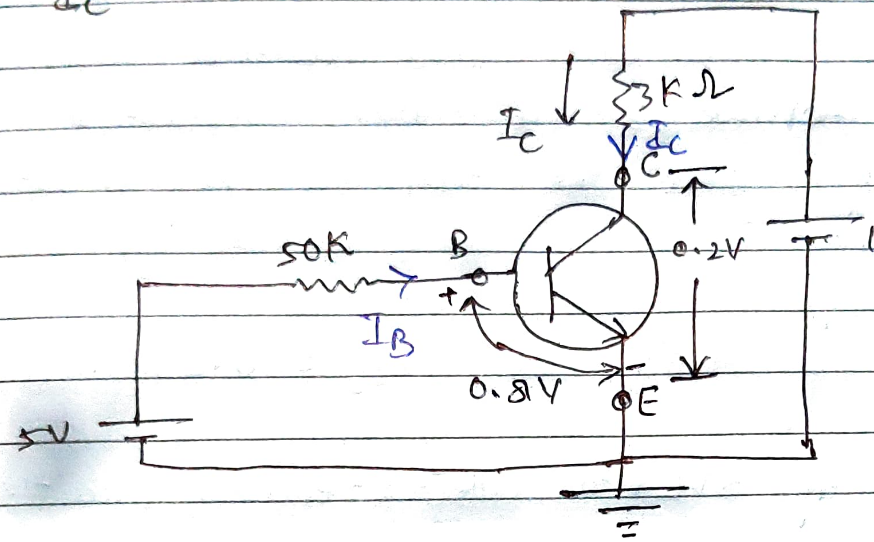
Q.12 (Q.4(a) of 4.2) In the figure, if $\beta = 100$, determine whether or not the silicon transistor is in saturation mode and find I_B and I_C.



Assuming the transistor to be in ~~saturation~~ active mode,

Applying KVL to base circuit,

$$5 - (50K) I_B - 0.8 = 0$$

$$I_B = \frac{4.2}{50K} = 0.084\, mA$$

$$\therefore I_C = \beta I_B = 8.4\, mA$$

$$\text{and } I_E = I_B + I_C = 8.484\, mA$$

$$\therefore V_C = 10 - (3K) I_C = -15.2\, V$$

$$V_B = 0.8V$$
$$V_E = 0V$$

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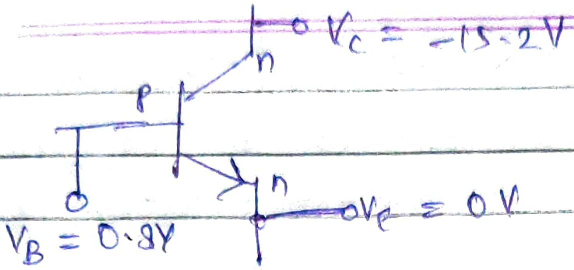
Now,



As the emitter base and collector base junction are ~~forward~~ biased, our assumption is wrong and the transistor is in saturation mode.

In saturation mode, $V_{CE} = 0.2V$

Applying KVL to collector-emitter circuit;

$$10 - I_C R_C - 0.2 = 0$$

$$I_C = \frac{9.8}{(3k\Omega)} \approx 3.27\,mA$$

$$\therefore I_B = \frac{I_C}{\beta} = \frac{3.27\,mA}{100} = 0.0327\,mA$$

$$I_B = 32.7\,\mu A$$

$\therefore$ $I_B = 32.7\,\mu A$ and $I_C = 3.27\,mA$.

Q.13 (4(b) of 4.2) In the figure, if $\beta = 100$, determine if transistor is in saturation mode or not and find I_B and I_C.

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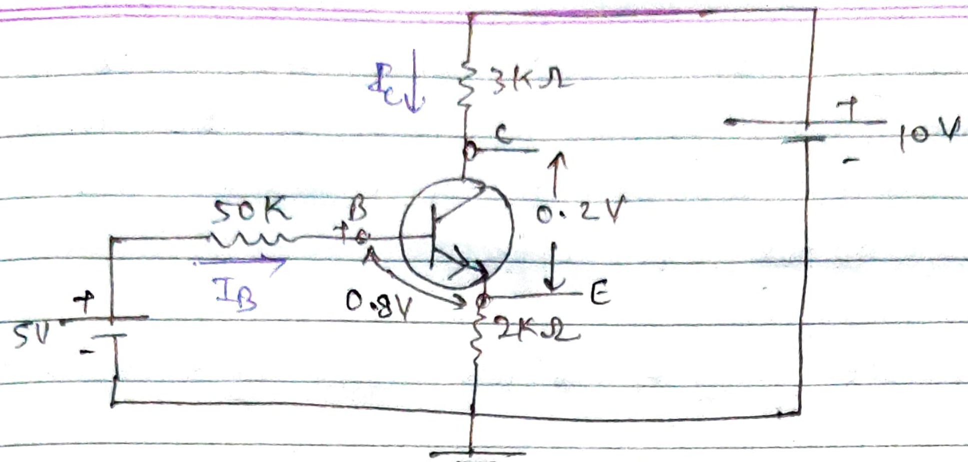


Assuming the transistor to be in active mode,

Applying KVL to base circuit

$$5V - (50K)I_B - 0.8 - (2K\Omega)I_E = 0$$

$$\therefore I_B = \frac{4.2}{(2K)(\beta+1) + 50K} \qquad \left(\because I_E = (\beta+1) I_B\right)$$

$$I_B = \frac{4.2}{252K} = 0.0167\,mA$$

$$\therefore I_C = \beta I_B = 1.67\,mA$$

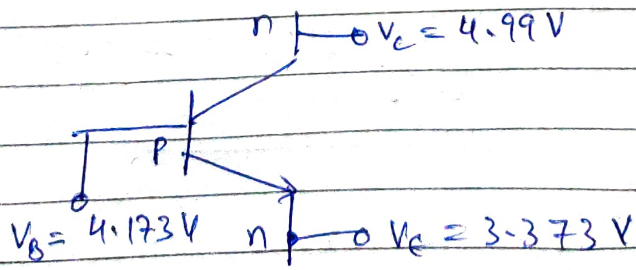
$$\therefore I_E = 1.6867\,mA$$

$$\therefore V_E = I_E R_E = 3.373\,V$$

$$V_C = 10 - I_C R_C = 4.99\,V$$

$$V_B = V_E + 0.8 = 4.173\,V$$

Now,



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Clearly, $V_{BE} \geq 0.7$ and $V_{CB} \geq 0.7$.
Hence, the emitter junction is FB and collector junction is RB. Hence, our assumption is correct.

Therefore, $I_C = 1.67\,mA$ and $I_B = 16.7\,\mu A$.

Q.14 (Ex 8.3 of 4.2) Determine the values of emitter current and collector current of a transistor having $\alpha_{dc} = 0.98$ and collector to base leakage current $I_{CBO} = 4\,\mu A$. The base current is $50\,\mu A$.

Given $\alpha = 0.98$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{0.02} = 49$$

given $I_{CBO} = 4\,\mu A$ and $I_B = 50\,\mu A$.

$\therefore I_{CO} = (1+\beta) I_{CBO} = 50 \times 4\,\mu A = 200\,\mu A$

collector current, $I_C = \beta I_B + I_{CEO}$

$= 49 \times 50\,\mu A + 200\,\mu A$

$= 2650\,\mu A$

$$\boxed{I_C = 2.650\,mA}$$

$\therefore$ emitter current $(I_E) = I_B + I_C$

$= 2.650 + 0.05$

$$\boxed{I_E = 2.7\,mA}$$

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Q.15 Calculate β for two transistors for which $\alpha = 0.99$ and 0.98. For collector currents of 10mA, find the base current of each transistor.

If $\alpha = 0.99$,

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{0.01} = 99$$

$$I_B \,(\text{at } \beta = 99) = \frac{I_C}{\beta} = \frac{10\,mA}{99} = 0.101\,mA$$

$$I_B \,(\text{at } \beta = 99) = 101\,\mu A$$

If $\alpha = 0.98$,

$$\beta = \frac{0.98}{0.02} = 49$$

$$I_B \,(\text{at } \beta = 49) = \frac{I_C}{\beta} = \frac{10\,mA}{49} = 0.204\,mA$$

$$I_B \,(\text{at } \beta = 49) = 204\,\mu A$$