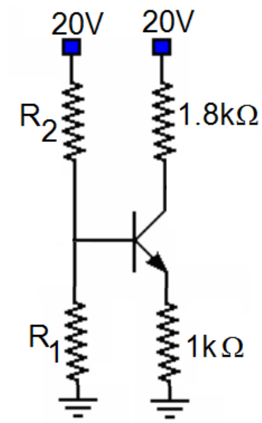
Electronics

BJT biasing

Problem 1.- In the following circuit, we want to set the transistor in the middle of the active region, that is $V_{CE-Q} = 10V$ for $\beta = 100$

Find values of R_1 and R_2 to accomplish this.

You can use the simplified rule $R_1 // R_2 \approx \frac{\beta R_E}{10}$



Solution.- The DC analysis gives us:

$$I_{CQ} = \frac{20-10}{1.8k+1k} = 3.57mA\text{, then } I_{BQ} = \frac{3.57mA}{100} = 35.7\mu A$$

The base voltage will be: $V_B = 0.7V + 1k\Omega \times 3.57mA = 4.27V$

Using the criterion given the Thevenin resistance is $R_1 // R_2 = 10k\Omega$

And the Thevenin voltage

$$V_{Th} = 4.27V + 10k\Omega \times 35.7\mu A = 4.63V$$

Which gives us $R_1 = \frac{4.63}{20}R$ and $R_2 = \frac{20-4.63}{20}R = \frac{15.37}{20}R$

Plugging in the Thevenin resistance:

$$R_1 // R_2 = 10k\Omega = \frac{\frac{4.63}{20}R \times \frac{15.37}{20}R}{\frac{4.63}{20}R + \frac{15.37}{20}R} = \frac{4.63 \times 15.37}{20 \times 20}R \rightarrow R = 56.2k\Omega$$

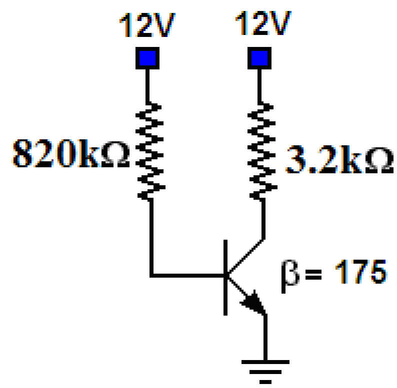
Then

$R_1 = 13.0k\Omega$

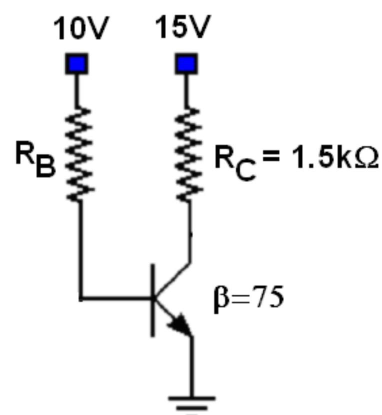
$R_2 = 43.2k\Omega$

This is not a unique solution.

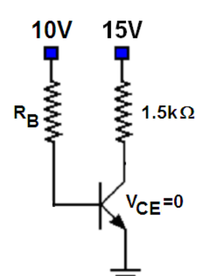
Problem 2.- If beta is 175, calculate I_B, V_{CE}, and the power consumed by the transistor in that condition.



Problem 3.- Calculate the maximum value of R_B that still puts the transistor in saturation.



Solution: If the transistor is saturated, the voltage collector emitter will be very low. Let us assume it is zero, so the 15V of the source has to drop across the collector resistor:



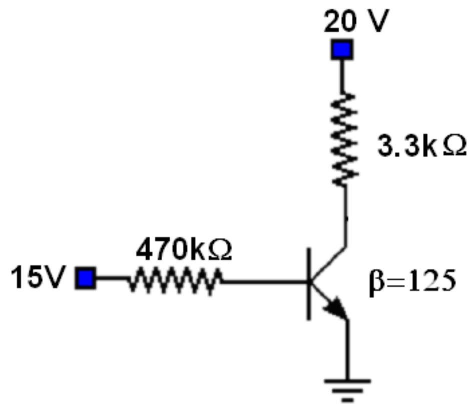
That means: $I_C = \frac{15V}{1.5k\Omega} = 10mA$, and taking into account that β is 75 for this transistor:

$$I_B = \frac{I_C}{\beta} = \frac{10mA}{75} = 133\mu A$$

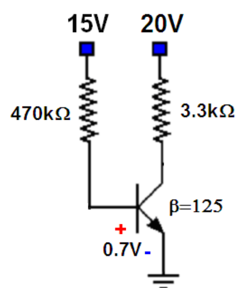
The base side of the transistor consists of a 10V source, a resistor and the base-emitter junction, which can be modeled by a 0.7V voltage drop. So, the loop equation will be:

$$10V = R_B I_B + 0.7V \rightarrow R_B = \frac{10V - 0.7V}{133\mu A} = \mathbf{70\ k\Omega}$$

Problem 4.- Find the Q point of the following transistor (that is, find I_B, V_{CE} and I_C). In what region is the transistor operating?



Solution: To find the Q-point of the transistor we first find the base current:



The loop equation gives us: $15V = 470k\Omega I_B + 0.7V \rightarrow I_B = \frac{15V - 0.7V}{470k\Omega} =$ **30.4µA**

The collector current is:

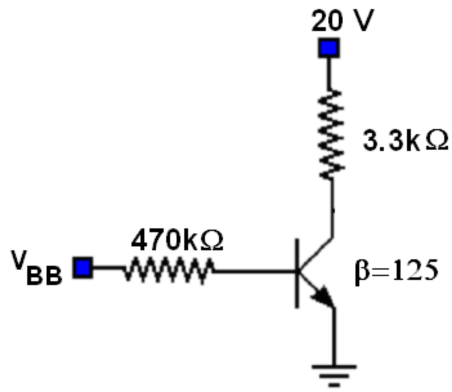
$I_C = \beta I_B = 125 \times 30.4\mu A =$ **3.8µA**

To get the voltage collector emitter we write the loop equation for the collector side:

$20V = 3.3k\Omega I_C + V_{CE} \rightarrow V_{CE} = 20V - 3.3k\Omega(125 \times 30.4\mu A) =$ **7.45V**

The transistor is in the active region.

Problem 5.- Calculate the voltage V_{BB} that will saturate the transistor. Also indicate the voltage V_{BB} that will put the transistor in cut-off.



Solution: When the transistor is in saturation the voltage collector emitter is very low (recall from your experiments in the lab that it is typically $\approx 0.1V$), so we can say that all the voltage of the power supply is across the 3.3kohm resistor, then the collector current is:

$$I_C = \frac{20V}{3.3k\Omega} = 6.06mA$$

Now, we can calculate the minimum base current that will produce this collector current. All we need to do is divide by beta:

$$I_B = \frac{I_C}{\beta} = \frac{6.06mA}{125} = 48.5\mu A$$

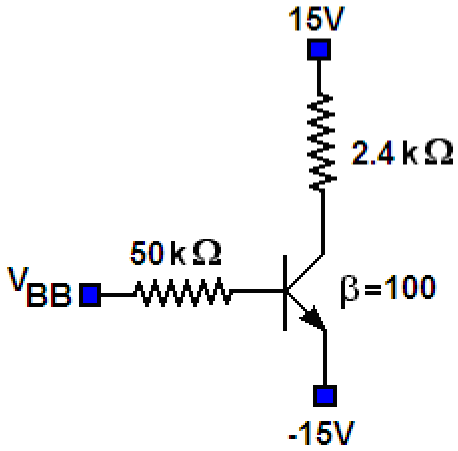
Notice that the voltage V_{BB} is equal to the drop in the 470kohm resistor plus the voltage base-emitter, which is 0.7V, then:

$$V_{BB} = 470k\Omega I_B + 0.7V = 470k\Omega(48.5\mu A) + 0.7V = \mathbf{23.5\ V}$$

This voltage will saturate the transistor.

On the other hand, to put the transistor in cut-off, the voltage V_{BB} should be **0.7V** or less, because then the base current will be zero and the collector-emitter will behave as an open circuit.

Problem 6.- If you decrease the voltage V_{BB}, at what value will you put the transistor in cutoff?



Solution: The voltage base-emitter has to be 0.7 or less for the transistor to be in cutoff, so V_{BB} has to be less than **-14.3 V**