Bipolar Junction Transistors

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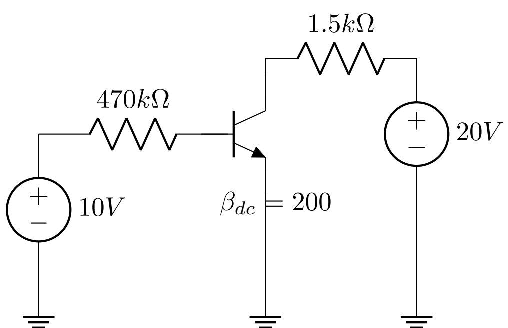
Question 1. A transistor circuit has a collector supply voltage of 20V, a collector resistance of 1.5KΩ, and a collector current of 6mA, what is the collector emmiter voltage?



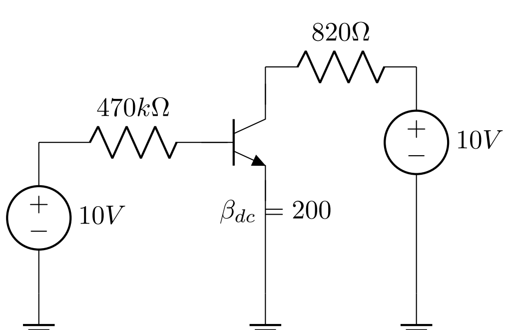
Using kirchoff voltage law

20V - I_c * 1.5$k\Omega$ - V_{CE}=0
20V - 1.5$k\Omega$* 6mA = V_{CE}
20V - 9V = V_{CE}
V_{CE} = 11V

Question 2 If a transistor has a collector current of 100mA and a collector-emitter voltage of 3.5V, what its power dissipation

Collector current = I_c = 100mA
V_{CE} = 3.5 V
P=I_c * V_{CE}
P = 100mA *3.5V
P = 350mW

Question 3 What are the collector -emitter voltage and the transistor power dissipation? (Give Answers for the ideal and the second approximation)



Ideal approximation

Using kirchhoff's Voltage law
10V - 470$k\Omega$ * I_b=0
I_b = 21.3μA

I_c = $\beta * I_b$
I_c = 200 * 21.3μA
I_c = 4.26mA

V_{CE} = 10V - 820Ω * I_c
V_{CE}= 10V - 820Ω* 4.26mA
V_{CE}= 6.51V

P_{CE} = V_{CE} * I_c
P_{CE} = 6.51V*4.26mA
P_{CE} = 27.8mW

Second approximation

Using kirchhoff's Voltage law

10V - 470$k\Omega$ * I_b=0
I_b = (10V - V_{be}) / 470$k\Omega$

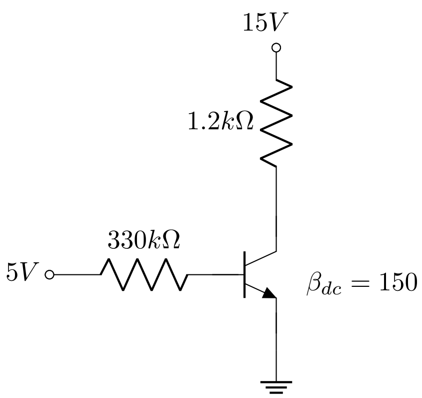
Assuming V_{be} = 0.7V
I_b = (10V - 0.7V) / 470$k\Omega$
I_b =19.8 μA

I_c = $\beta * I_b$
I_c = 200 *19.8μA
I_c = 3.96mA

V_{CE} = 10V - 820Ω*I_c
V_{CE}= 10V - 820Ω*3.96mA
V_{CE}= 6.76V

P_{CE} = V_{ce} * I_c
P_{CE} = 6.76V*3.96mA
P_{CE} = 26.77mW

Question 4 Circuit below shows a simpler way to draw a transistor circuit it works the same as the circuits already discussed. What is collector- emitter voltage? The transistor power dissipation?(give answer for the ideal and the second approximation



Ideal approximation

Using kirchhoff's Voltage law
5V - 330$k\Omega$ * I_b=0
I_b =15.15μA

I_c = $\beta * I_b$
I_c = 150 *21.3μA
I_c = 2.27mA

V_{CE} = 15V - 1.2$k\Omega$*I_c
V_{CE}= 15V - 1.2$k\Omega$*2.27mA
V_{CE}= 12.3V

P_{CE} = V_{CE} * I_c
P_{CE} = 12.3V*2.27mA
P_{CE} = 27.9mW

Second approximation

Using kirchhoff's Voltage law
I_b = (10V - V_{be}) / 330$k\Omega$

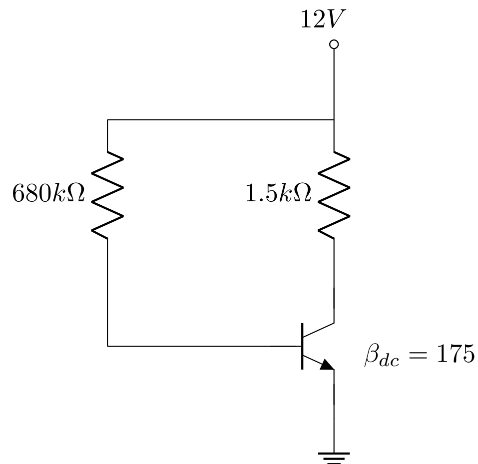
Assuming V_{be} = 0.7V
I_b = (10V - 0.7V) / 330$k\Omega$
I_b =13μA

I_c = $\beta * I_b$
I_c = 150 *13μA
I_c = 1.95mA

V_{CE} = 10V - 1.2$k\Omega$*I_c
V_{CE}= 10V - 1.2$k\Omega$*1.95mA
V_{CE}= 12.7V

P_{CE} = V_{ce} * I_c
P_{CE} = 12.7V*1.95mA
P_{CE} = 24.7mW

Question 5. When the base and collector supplies are equal, the transistor can be drawn as shown in below. What is the collector-emitter voltage in this circuit? the transistor power? (Give answers for the ideal and the second approximation)



Ideal approximation

Using kirchhoff's Voltage law
12V - 680$k\Omega$ * I_b=0
I_b = 17.65μA

I_c = $\beta * I_b$
I_c = 175 * 17.65μA
I_c = 3.1mA

V_{CE} = 12V - 1.5$k\Omega$*I_c
V_{CE}= 12V - 1.5$k\Omega$*3.1mA
V_{CE}= 7.35V

P_{CE} = V_{ce} * I_c
P_{CE} = 7.35V*3.1mA
P_{CE} = 22.79mW

Second approximation

Using kirchhoff's Voltage law
I_b = (12V - V_{be}) / 680$k\Omega$

Assuming V_{be} = 0.7V
I_b = (12V - 0.7V) / 680$k\Omega$
I_b =16.62μA

I_c = $\beta * I_b$
I_c = 175 * 16.62μA
I_c = 2.91mA

V_{CE} = 12V - 1.5$k\Omega$*I_c

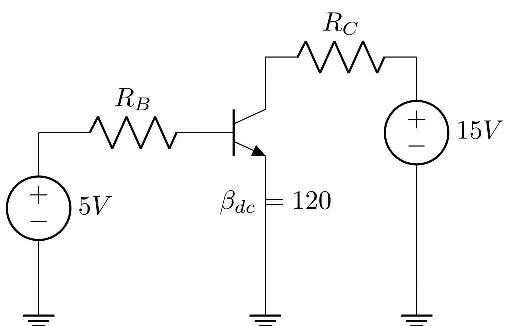
V_{CE}= 12V - 1.5$k\Omega$*2.91mA
V_{CE}= 7.64V

P_{CE} = V_{CE} * I_c
P_{CE} = 7.64V*2.91mA
P_{CE} = 22.23mW

Question 6 What is the current gain of a transistor with a dc alpha of 0.994?

α = β/(β+1)
0.994 = β/(β+1)
(β+1)*0.0994 = β
0.994*β + 0.994 = β
0.994 = (1-0.994) *β
0.994/ (1-0.994) = β
β = 165.66

Question 7 Design a CE circuit to meet these specifications: V_{bb} = 5v, V_{CC} = 15v, H_{FE} = 120, I_C = 10mA, V_{CE} = 7.5V

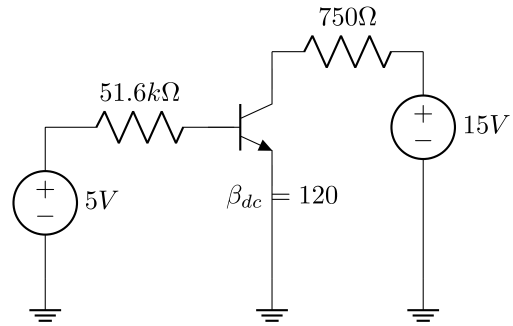


If I_C = 10mA
I_C = β * I_b = 10mA
I_b = I_C/120 = 83.33μA

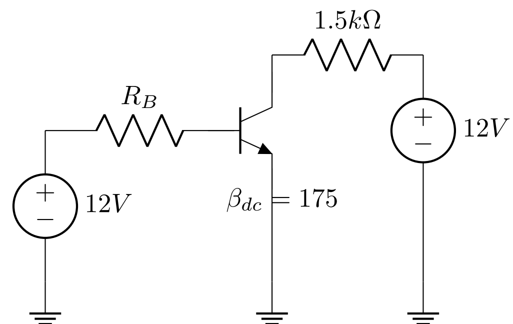
Using kirchoff's voltage law.

5V - I_b*R_b - 0.7V = 0
5V - 83.33μA*R_b - 0.7V = 0
R_b = 4.3V/83.33μA = 51.6kΩ

Using kirchoff's voltage law.
15V - I_C*R_C - V_{CE} = 0
(15V - V_{CE}) / I_C = R_C
(15V - 7.5V) / 10mA = R_C
(15V - 7.5V) / 10mA = R_C
R_C = 750Ω



Question 8 In the Circuit below, what value base resistor would be needed so V_{CE} = 6.7V



(12V - V_{CE})/R_C = I_C
(12V - 6.7V)/R_C = I_C
I_C = (12V - 6.7V)/1.5$k\Omega$ = 3.533mA

I_C = β * I_B
I_B = I_C / β = 3.533mA/175 = 20.1μA

12V - I_B*R_B - V_{BE} = 0
11.3/I_B = R_B
R_B = 11.3/20.1μA = 559kΩ

Question 9 A 2N3904 has a power rating of 350 mW at room temperature (25 C). If the collector-emitter voltage is 10V, what is the maximum current that the transistor can handle for an ambient temperature of 50C.

The change in temperature is 50C - 25C which is 25C.

derating factor is (5 mW/C)
The change in temperature is 25C
Thus (5 mW/C) * 25C = 125mW

Subtracting the difference in power rating in 25C
350 mW - 125mW = 225mW

Thus, The power rating of 2N3904 at ambient temperature 50C is 225mW

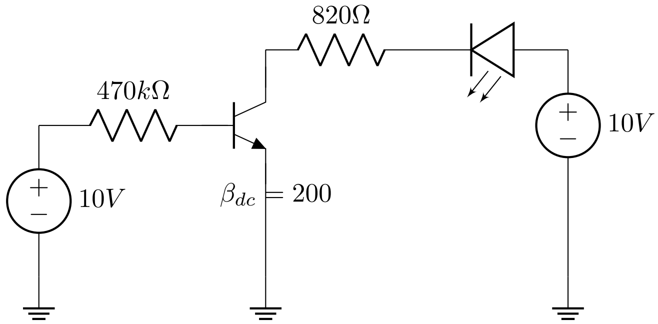
knowing that V_{CE} * I = P

10V * I = 225mW

I = 22.5mA

Thus maximum current that the transistor can handle for an ambient temperature of 50C is 22.5mA

Question 10 Suppose we conncect an LED in series with the 820Ω of Fig 6-20. What does the LED current equal?



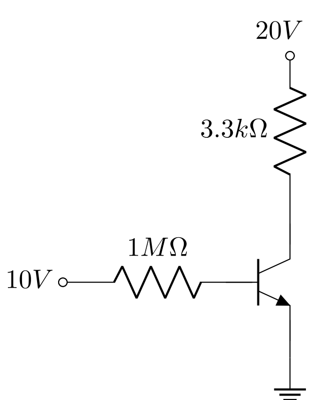
I_b = (10V - V_{be}) / 470$k\Omega$

Assuming V_{be} = 0.7V
I_b = (10V - 0.7V) / 470$k\Omega$
I_b =19.8 μA

I_c = $\beta * I_b$
I_c = 200 *19.8μA
I_c = 3.96mA

Thus, LED current equals to 3.96mA

Question 11 Draw the load line for Circuit below. What is the collector current at the saturation point? The collector - emitter voltage at the cutoff point?



Using Kirchhoff's voltage law

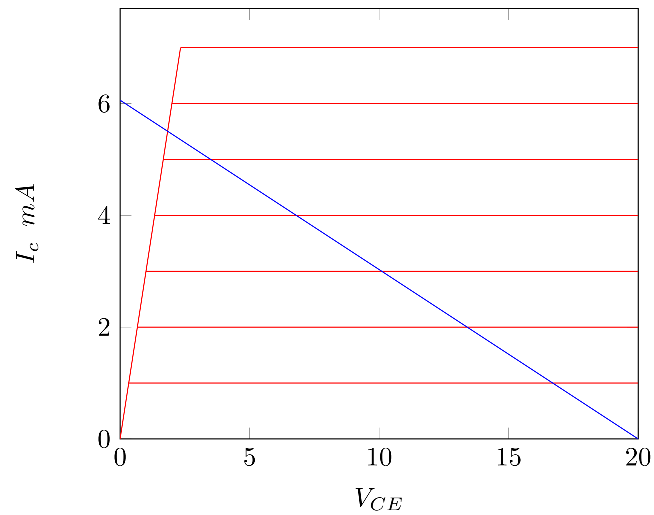
20V - I_c * 3.3k Ω - V_{CE} = 0
I_c = (20V - V_{CE}) / 3.3$k\Omega$

To find collector current at saturation point. substitute V_{CE} to 0.

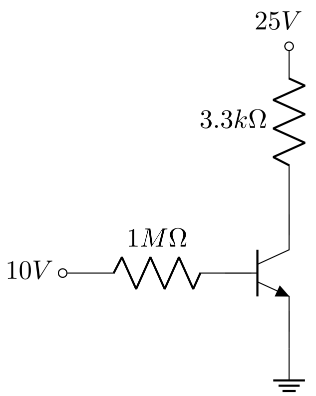
I_c = (20V - 0) / 3.3$k\Omega$
I_c = 6.06mA at V_{CE} = 0

To find collector-emitter voltage at the cutoff point, substitute I_c to 0.

I_c = (20V - V_{CE}) / 3.3$k\Omega$
0 = (20V - V_{CE}) / 3.3$k\Omega$
V_{CE} = 20V at I_c = 0



Question 12 If the collector supply voltage is increased to 25V in the circuit below, what happens to the load line?



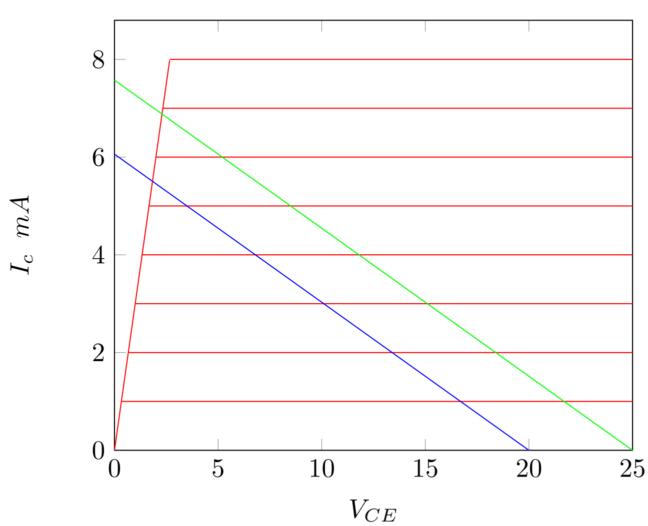
Using Kirchhoff's voltage law

25 - I_c * 3.3k Ω - V_{CE} = 0
I_c = (25V - V_{CE}) / 3.3$k\Omega$

To find collector current at saturation point. substitute V_{CE} to 0.
I_c = (25V - 0) / 3.3$k\Omega$
I_c = 7.57mA at V_{CE} = 0

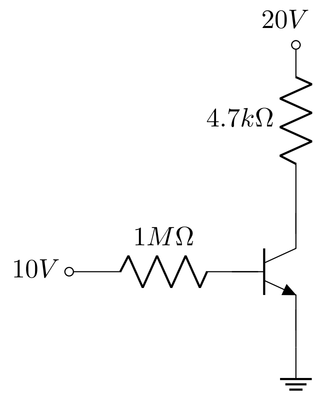
To find collector-emitter voltage at the cutoff point, substitute I_c to 0.

I_c = (25V - V_{CE}) / 3.3$k\Omega$
0 = (25V - V_{CE}) / 3.3$k\Omega$
V_{CE} = 25V at I_c = 0



As the collector supply voltage increases, the collector current at saturation point and the collector emitter voltage at the cutoff point increases.

Question 13 If the collector resistance is increased to 4.7 kΩ in the Circuit Below, what happens to the load line?



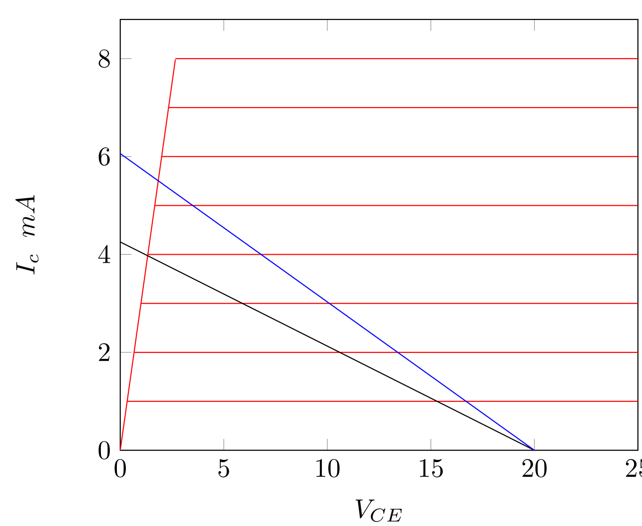
Using Kirchhoff's voltage law

20 - I_c * 4.7k Ω - V_{CE} = 0
I_c = (20V - V_{CE}) / 4.7$k\Omega$

To find collector current at saturation point. substitute V_{CE} to 0.
I_c = (20V - 0) / 4.7$k\Omega$
I_c = 4.25mA at V_{CE} = 0

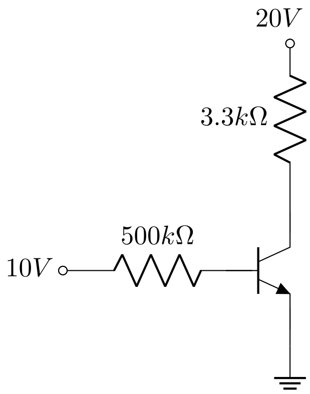
To find collector-emitter voltage at the cutoff point, substitute I_c to 0.

I_c = (20V - V_{CE}) / 4.7$k\Omega$
0 = (20V - V_{CE}) / 4.7$k\Omega$
V_{CE} = 20V at I_c = 0



As the collector resistance increase, the slope of load line decreases.

Question 14. As the base resistance of is reduced to 500kΩ. What happens to the load line?



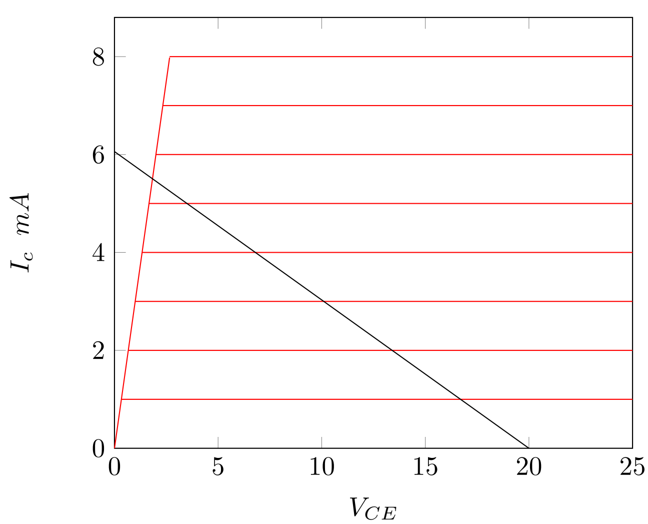
Using Kirchhoff's voltage law

20 - I_c * 3.3k Ω - V_{CE} = 0
I_c = (20V - V_{CE}) / 3.3kΩ

To find collector current at saturation point. substitute V_{CE} to 0.
I_c = (20V - 0) / 3.3kΩ
I_c = 6.06mA at V_{CE} = 0

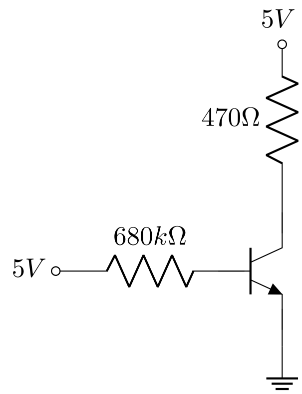
To find collector-emitter voltage at the cutoff point, substitute I_c to 0.

I_c = (20V - V_{CE}) / 3.3kΩ
0 = (20V - V_{CE}) / 3.3kΩ
V_{CE} = 20V at I_c = 0



As the base resistance change, the load line does not change.

Question 15 Draw the load line for circuit below. What is the collector current at the saturation point? The collector - emitter voltage at the cut off point?



Using Kirchhoff's voltage law

5V - I_c * 470Ω - V_{CE} = 0
I_c = (5V - V_{CE}) / 470Ω

To find collector current at saturation point. substitute V_{CE} to 0.
I_c = (5V - 0) / 470Ω
I_c = 10.64mA at V_{CE} = 0

To find collector-emitter voltage at the cutoff point, substitute I_c to 0.

I_c = (5V - V_{CE}) / 470Ω
0 = (5V - V_{CE}) / 470Ω

V_{CE} = 5V at I_c = 0