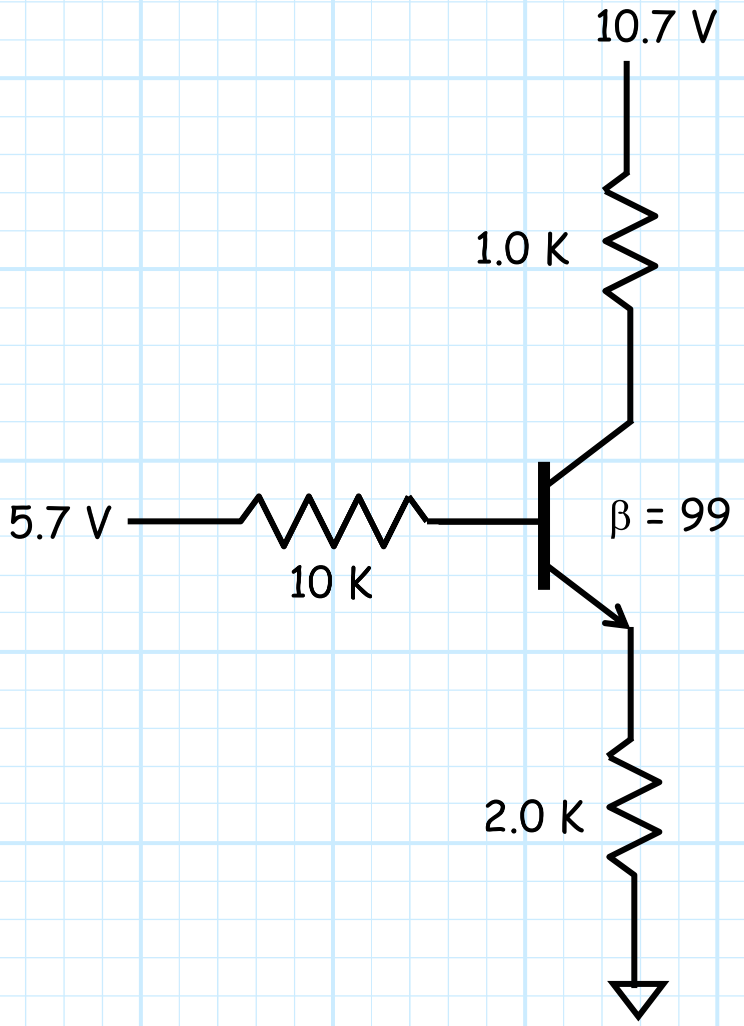
Example: D.C. Analysis of a BJT Circuit

Consider **again** this circuit from lecture:



Q: *What is I_B, I_C, I_E and also V_{CE}, V_{CB}, V_{BE} ??*

A: I don't know ! But, we can find out—IF we complete **each** of the five steps **required** for BJT DC analysis.

Step 1 - **ASSUME** an operating mode.

Let's ASSUME the BJT is in the ACTIVE region !

Remember, this is just a **guess**; we have no way of knowing for sure what mode the BJT is in at this point.

Step 2 - **ENFORCE** the conditions of the assumed mode.

For **active** region, these are:

$$V_{BE} = 0.7\ V \quad \text{and} \quad I_C = \beta\, I_B = 99\, I_B$$

Step 3 - **ANALYZE** the circuit.

This is the **BIG** step !

Q: *Where do we even start ?*

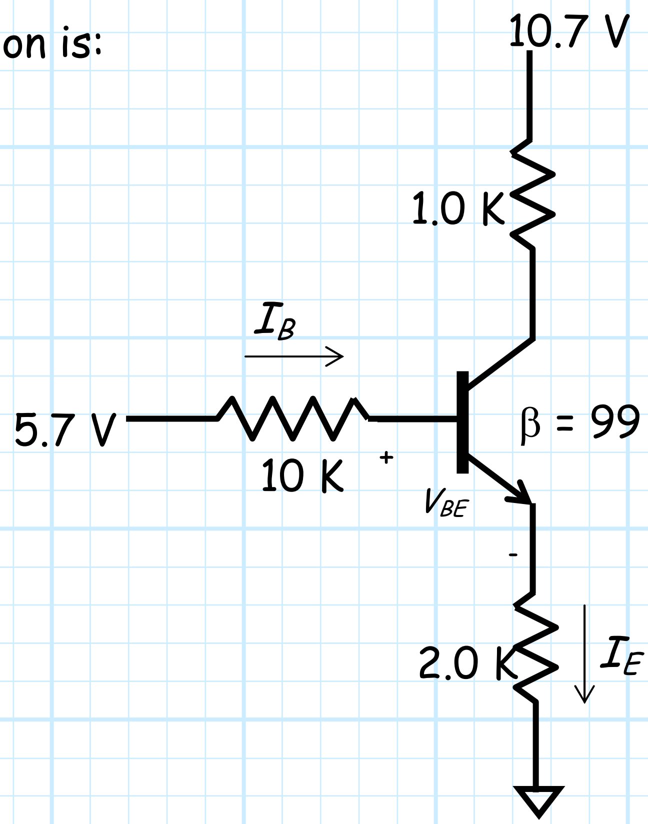
A: Recall what the hint sheet says:

"Write KVL equations for the base-emitter "leg"

I think we should try that !

The **base-emitter KVL** equation is:

$$5.7 - 10\,I_B - V_{BE} - 2\,I_E = 0$$



This is the **circuit** equation; note that it contains 3 unknowns (i_B, i_C, and V_{BE}).

Now let's add the relevant **device** equations:

$$V_{BE} = 0.7\ V$$

$$I_E = (\beta + 1)\, I_B = 100\, I_B$$

Look what we now have ! **3** equations and **3** unknowns (this is a **good** thing).

Inserting the device equations into the B-E KVL:

$$5.7 - 10\,I_B - 0.7 - 2(99+1)I_B = 0$$

Therefore:

$5.0 - 210\,I_B = 0$ ➡ 1 equations and 1 unknown !

Solving, we get:

$$I_B = \frac{5.0}{210} = \underline{23.8\ \mu A}$$

Q: *Whew ! That was an **awful** lot of work for just one current, and we still have **two more** currents to find.*

A: No we don't ! Since we determined **one** current for a BJT in **active** mode, we've determined them **all** !

I.E.,

$$I_C = \beta\ I_B = \underline{2.356\ \text{mA}}$$

$$I_E = (\beta + 1)\ I_B = \underline{2.380\ \text{mA}}$$

(Note that $I_C + I_B = I_E$)

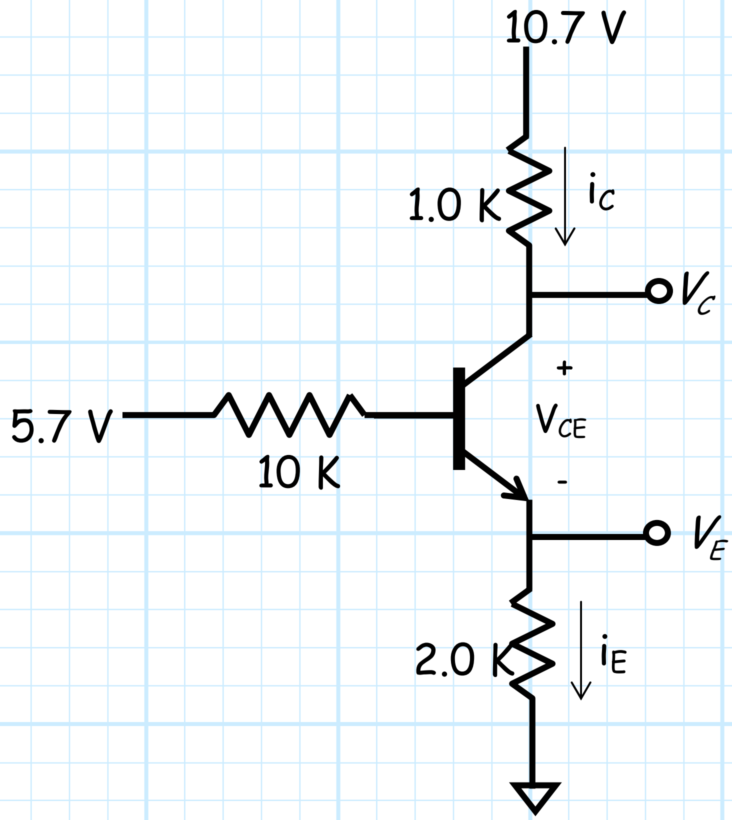
Now for the **voltages** !

Since we know the **currents**, we can find the voltages **using KVL**.

For example, let's **determine** V_{CE}. We can do this **either** by finding the voltage at the **collector** V_C (wrt ground) and voltage at the **emitter** V_E (wrt ground) and then subtracting ($V_{CE} = V_C - V_E$).

OR, we can determine V_{CE} **directly** from **the C-E KVL equation**.

$$\begin{aligned} V_C &= 10.7 - I_C(1) \\ &= 10.7 - 2.36 \\ &= 8.34 \quad \text{V} \end{aligned}$$



and:

$$\begin{aligned} V_E &= 0 + I_E(2) \\ &= 0 + 4.76 \\ &= 4.76 \quad \text{V} \end{aligned}$$

Therefore,

$V_{CE} = V_C - V_E =$ <u>3.58 V</u>

Note we could have **likewise** written the C-E KVL:

$$10.7 - I_C(1) - V_{CE} - I_E(2) = 0$$

Therefore,

$$V_{CE} = 10.7 - I_C(1) - I_E(2) = 3.58 \quad \text{V}$$

Q: *So, I guess we write the collector-base KVL to find V_{CB} ?*

A: You can, but a **wiser** choice would be to simply apply **KVL** to the **transistor** !

I.E., $V_{CE} = V_{CB} + V_{BE}$!!

Therefore $V_{CB} = V_{CE} - V_{BE} = \underline{2.88 \text{ V}}$

Q: *This has been **hard**. I'm glad we're finished !*

A: Finished ! We still have **2 more** steps to go!

Step 4 - CHECK to see if your results are **consistent** with your assumption.

For **active** mode:

$$V_{CE} = 3.58 \text{ V} > 0.7 \text{ V} \checkmark$$

$$I_B = 23.8 \text{ } \mu\text{A} > 0.0 \checkmark$$

Are assumption was **correct**, and therefore so are our **answers** !

No need to go on to Step 5 .