Write your name at the top right corner of every page (including this cover page).

Copy everything you want counted towards your grade onto the pages that I provided.

Write with a pen that cannot be erased!

No books or calculators are allowed!

Write down all the steps that lead to your result.

Identify new variables that you may introduce in the circuit diagrams that I provided.

Read all the problems before you start so that you can begin with those that seem easiest to you.

Problem 1 (10 pts):

Mark the *correct* correspondence with an X in the appropriate row/column combination:

a.) Which equation applies for which kind of transistor?

equation	BJT	FET
$i_C = I_S(e^{v_{EB}/V_T} - 1)$	X	
$i_D = I_{DSS}(1 - v_{GS}/V_p)^2$		X

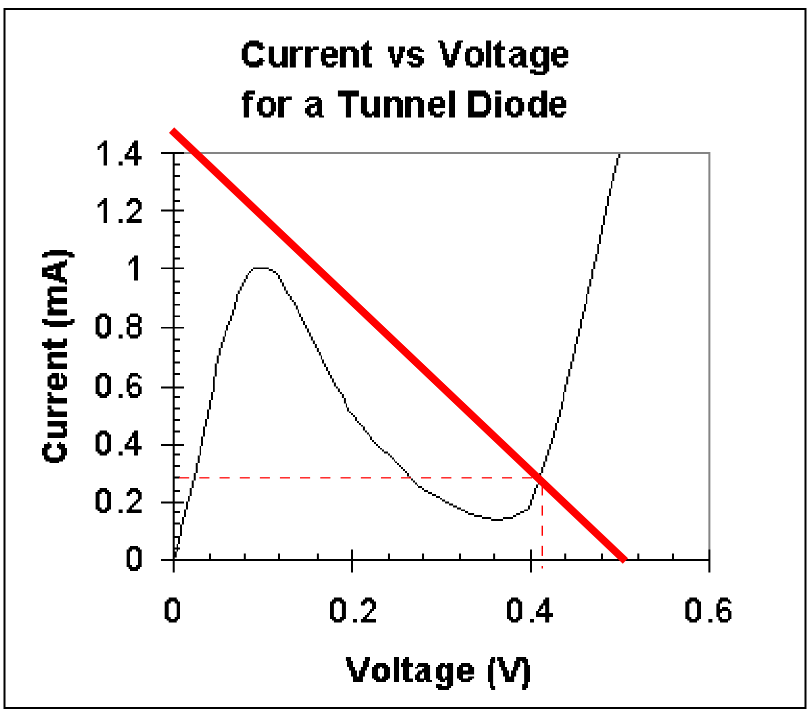
(continuation of problem 1)

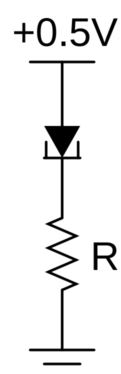
b.) Some of the symbols used in the equations above stand for parameters and others for variables. Parameters are determined by the manufacturing process and physical design of the transistor, while the values of (dependent as well as independent) variables are determined by your circuit design. Given this distinction the parameters are the ones that have to be looked up in data sheets or be derived from nature's fundamental constants, while the variables are what you solve for when analyzing your circuits. Which of the following symbols represent parameters?

parameter?	Yes	No
i_C		X
I_S	X	
v_{BE}		X
V_T	X	
i_D		X
I_{DSS}	X	
v_{GS}		X
V_p	X	

Problem 2 (4 pts):

Below you see one quadrant of the I-V characteristics of a tunnel diode. (It does not matter for the problem that we did not discuss this particular device in the lectures! The modified diode symbol in the circuit is the usual symbol for this kind of diode.) Use load line analysis to find the voltage drop across the tunnel diode if the resistor has the value $\mathrm{R} = 1/3\mathrm{k}\Omega$



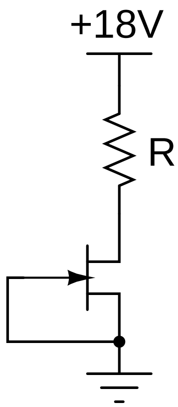


Solution: The graphic solution is now superimposed in red with the original figure. If all the voltage drops off across the resistor, a maximal current of $I_{max} = 0.5\mathrm{V}/0.33\mathrm{k}\Omega = 1.5\mathrm{mA}$ will flow. If no current flows, the voltage drop across the resistor is $0\mathrm{V}$ and that would mean that all the voltage would have to be across the tunnel diode.

As the voltage drop across the resistor increases linearly with the current, the load line for the resistor is straight red line between the two points with the (x,y)-coordinates (0,1.5) and (0.5,0) in the graph. It intersects the tunnel diode's I-V curve in exactly one point (0.41,0.28). So the operating point will be where a current of approximately 280μA will flow through both, the resistor and the tunnel diode, and a voltage drop of approximately 0.41V is observed at the tunnel diode.

Problem 3 (6 pts):

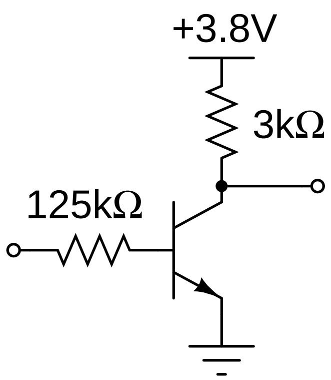
The JFET in the following circuit has parameters $I_{DSS} = 8$mA and $V_p = -4$V. Find the current through the resistor $\mathrm{R} = 500\Omega$. After your calculation verify that the transistor indeed is in the active region.



Solution: From $i_D = I_{DSS}(1 - v_{GS}/V_p)^2 = 8\mathrm{mA}(1 - 0/(-4\mathrm{V}))^2$ we get directly that $i_D = 8\mathrm{mA} = \mathrm{I_{DSS}}$ - if the FET is in its active region.
By KVL: $v_{DS} = 18\mathrm{V} - \mathrm{Ri_D} = 18\mathrm{V} - 500\Omega 8\mathrm{mA} = 14\mathrm{V}$.
Therefore v_{DS} is larger than $v_{GS} - V_p = 0 - (-4\mathrm{V}) = 4\mathrm{V}$, i.e. this JFET is in the active region.

Problem 4 (6 pts):

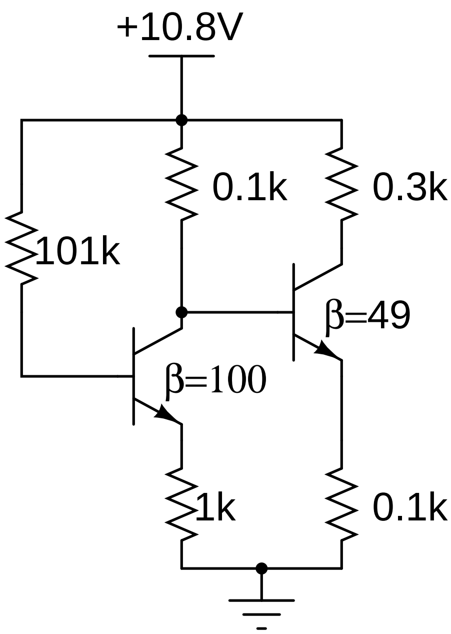
Below you find a simple logical inverter. So when its input goes high (3.8V), the transistor should saturate as to have the minimum possible output voltage. What is the minimal β the transistor must have to saturate at an input voltage of 3.8V given the resistors as shown?



Solution: Saturation means that v_{CE} is at its absolute minimum: $v_{CE} = 0.2\text{V}$. Therefore i_C must be big enough to produce a voltage drop of 3.8V-0.2V=3.6V across the 3kΩ resistor (i_C cannot grow any bigger then as v_C cannot go any lower):
$i_{C,max} = 3.6\text{V}/3\text{k}\Omega$. With $i_C = \beta i_B$ and $i_B = (3.8\text{V} - 0.8\text{V})/125\text{k}\Omega$, we get:
$\beta_{min} = i_{C,max}/i_B = (9x0.4x125)/9 = 50$

Problem 5 (6 pts):

Calculate the base current into the $\beta = 49$ transistor under the active region assumption for both transistors and show that it is in saturation.



Note: After being alerted by a student I realized that the resistor values were wrong: The 0.1kΩ resistors should both be 1kΩ resistors. This was announced to the class 40 minutes into the test, and, as almost everybody still turned in their test before the deadline, in time to allow for the easier calculation. It was also announced that the change in resistor values makes for the second transistor to be in the active region, and that this was to be shown. - Sorry for the mistake and confusion...

Solution: KVL gives: $10.8\mathrm{V} = 101\mathrm{k}\Omega \mathrm{i}_{\mathrm{B1}} + 0.7\mathrm{V} + 1\mathrm{k}\Omega(\beta_1 + 1)\mathrm{i}_{\mathrm{B1}}$, which yields: $i_{B1} = 50\mu\mathrm{A}$. This implies that $i_{C1} = 5\mathrm{mA}$. For the second stage we get by KVL again: $10.8\mathrm{V} = 1\mathrm{k}(\mathrm{i_{B2}} + \mathrm{i_{C1}}) + 0.7\mathrm{V} + 1\mathrm{k}(\beta_2 + 1)\mathrm{i_{B2}}$ $\Rightarrow 1\mathrm{k}\Omega\mathrm{i_{B2}} + 50\mathrm{k}\Omega\mathrm{i_{B2}} = 10.1\mathrm{V} - 1\mathrm{k}\Omega 5\mathrm{mA} = 5.1\mathrm{V}$ and therefore $i_{B2} = 100\mu\mathrm{A}$. That makes for $i_{C2} = 4.9\mathrm{mA}$ and $i_{E2} = 5\mathrm{mA}$, leading to: $v_{CE2} = (10.8 - 0.3 \times 4.9 - 5)\mathrm{V} > 4.3\mathrm{V} > 0.2\mathrm{V}$, QED.