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.

The last problem is for the Graduate Level students only. Undergraduate level students that solve the problem will get the earned points credited against their homework.

Problem 1 (9 pts):

In the table below please put a cross into the boxes where the condition stated for that row corresponds to the BJT condition stated for that column. Please leave open the boxes where that row condition about voltages and currents does not match the row condition of the BJT.

The *npn* BJT is:	active	saturated (ON)	cut-off (OFF)
$i_C = \beta i_B$	X		
$v_{BE} < 0.5$V			X
$v_{BE} \approx 0.7$V	X		
$i_C = i_B = i_E = 0$			X
$v_{BE} \approx 0.8$V and $v_{CE} \approx 0.2$V		X	
$\beta i_B \geq i_C$		X	

Please write the three corresponding voltage conditions for a *pnp* BJT.

For *pnp* transistors we have:
$v_{BE} > -0.5$V if the transistor is cut-off,
$v_{BE} \approx -0.7$V in the active region
$v_{BE} \approx -0.8$V and $v_{CE} \approx -0.2$V in saturation.

Problem 2 (5 pts):

Which of the following terms are allowed when you prepare your Transfer Function $\mathbf{H}(\mathbf{s})$ to sketch your Bode Plot? Mark "use" for those that are allowed, and "do not use" for those that are not allowed.

elementary form:	use	do not use
$(\frac{s^2+2\beta\gamma s+\gamma^2}{\gamma^2})^{\pm 1}$	X	
K	X	
$(\frac{s+\alpha}{\alpha})^{\pm 1}$	X	
$s^{\pm 1}$	X	
$(\frac{s^2-\delta^2}{\delta^2})^{\pm 1}$		X

Problem 3 (4 pts):

Use only the straight-line asymptotes to sketch the Bode Plot (both, amplitude and phase!) for the transfer function:

$H(j\omega) = \frac{j\omega}{a+j\omega}$ with $a > 0$.

What type of filter is this?

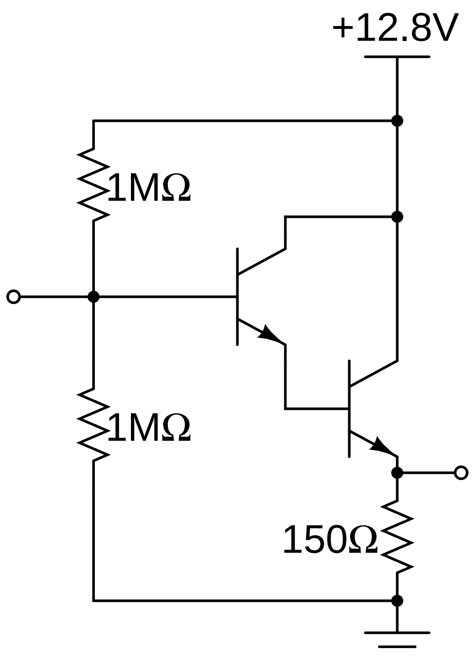
Solution: It is a high-pass filter. We express $H(j\omega)$ as the product:

$H(s) = \frac{1}{a} s \frac{a}{a+s}$

The resulting Bode Plots show a phase that drops from +90 degree up to $\omega = 0.1a$ to zero degree at $\omega = 10a$. Above $\omega = 10a$ the phase stays at zero degree. The resulting dB plot rises through -20dB at $\omega = 0.1a$ and hits 0dB at $\omega = a$. Above $\omega = a$ it stays at 0 dB.

Problem 4 (8 pts):

For the Darlington configuration below, find i_{B1}, if the transistors both have $\beta = 99$. i_{B1} is the base current into the first transistor. The first transistor is the one that has the second transistor's base connected to its emitter.



Solution: Let us call the two 1MΩ resistors R_1 and the 150Ω resistor R_2. The supply voltage shall be called V_{cc}. If i_1 is the current through the upper R_1 and i_2 the one through the lower R_1, then:

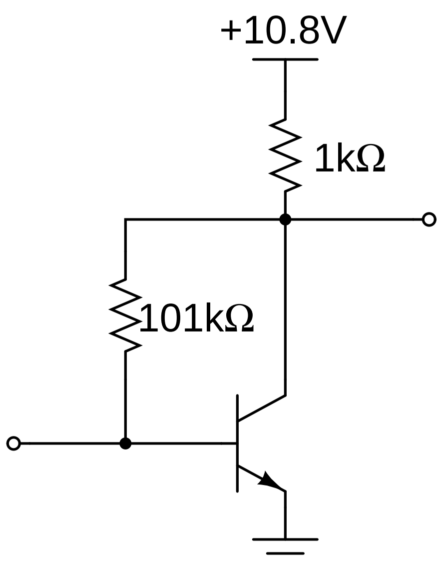
$i_1 = i_2 + i_{B1}$ and $V_{cc} = R_1(i_1 + i_2) = R_1(2i_1 - i_{B1}) \Rightarrow i_1 = \frac{1}{2}(\frac{V_{cc}}{R_1} + i_{B1})$

also: $i_{E2} = i_{B2} + i_{C2} = i_{B2} + \beta i_{B2} = (\beta+1)(i_{B1} + i_{C2}) = (\beta+1)^2 i_{B1}$

$V_{cc} = i_1 R_1 + 0.7\text{V} + 0.7\text{V} + \text{R}_2\text{i}_{\text{E}2}$
$\Rightarrow i_{B1}(R_1/2 + R_2(\beta+1)^2) = V_{cc}/2 - 1.4\text{V} \Rightarrow \text{i}_{\text{B}1} = 2.5\mu\text{A}$

Problem 5 (6 pts):

Below you find an example of collector feedback bias. Assuming that the transistor is operating in its active region and has $\beta = 100$, find i_B, i_C, and v_{CE}. Confirm that the transistor is in the active region.



Solution: Let us call the supply voltage V_{cc} and the two resistors R_1 and R_2, with R_1 being the resistor that is connected to V_{cc}. Then:

$V_{cc} = R_1(i_B + i_C) + R_2 i_B + V_{BE} = R_1(101 i_B) + R_2 i_B + 0.7\text{V}$

$\Rightarrow i_B = \frac{V_{cc} - 0.7\text{V}}{101 R_1 + R_2} = 50\mu\text{A} \Rightarrow i_C = 5\text{mA}$

$V_{CE} = V_{cc} - R_1(i_B + i_C)$ = 10.8V - 5.05V = 5.75V, which also proves that the transistor is in the active region.

Problem 6 (3 pts):

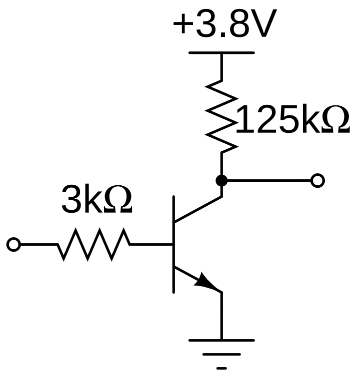
Put the following two sinusoids into phasor form and add the phasors:

$i_1(t) = 20\mathrm{A}cos(\omega t + 90°)$
$i_2(t) = 10\mathrm{A}sin(\omega t + 180°)$

Solution: j20 + j10 = j30; the angles are the same in both cases, as sin(180)=cos(180-90)=cos(90), i.e. 30A with an angle of +90 degree

Problem 7 ONLY 6610 students !!! (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: If we call the collector resistor R_C, the base resistor R_B, and the supply voltage V_{cc}, in saturation we will have:

$$i_C R_C = V_{cc} - 0.2\mathrm{V} = \beta \mathrm{i_B R_C}$$

The input current will be:

$$i_B R_B = V_{cc} - 0.8\mathrm{V}$$

Therefore:

$$\beta = \frac{i_C}{i_B} = \frac{R_B}{V_{cc} - 0.8\mathrm{V}} \frac{V_{cc} - 0.2\mathrm{V}}{R_C} = \frac{3.6\mathrm{V}}{3.0\mathrm{V}} \frac{3k\Omega}{125k\Omega} = 0.03$$

P.S. My mistake here: The values for R_C and R_B are swapped in the figure... (Would have been a wonderful β =50 if it wasn't - and the promised inverter...)