ECE137B Final Exam

There are 6 problems on this exam and you have 3 hours

Do not open this exam until told to do so
Show all work:
Credit will not be given for correct answers if supporting work is not shown.
Class Crib sheets and 4 pages of your own notes permitted.
Don’t panic.

<table>
<thead>
<tr>
<th>Time function</th>
<th>LaPlace Transform</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ(t)</td>
<td>1</td>
</tr>
<tr>
<td>U(t)</td>
<td>1/s</td>
</tr>
<tr>
<td>e^{-αt}U(t)</td>
<td>\frac{1}{s + α}</td>
</tr>
<tr>
<td>e^{-αt}cos(ω_d t)U(t)</td>
<td>\frac{s + α}{(s + α)^2 + ω_d^2}</td>
</tr>
<tr>
<td>e^{-αt}sin(ω_d t)U(t)</td>
<td>\frac{ω_d}{(s + α)^2 + ω_d^2}</td>
</tr>
</tbody>
</table>

Name: _________________________________
Problem 1, 20 points
transistor circuit analysis

part a, 5 points

In the circuit, the power supplies are +/- 10 volts. The transistors have beta=1000, ft=1 GHz, and Ccb=0.5 pF. CL=1 pF. Va=infinity.

Cee1 and Cbb2 are very large (AC short-circuits)

Rgen=1kOhm, Rb1=10 kOhm

Rb2a and Rb2b are chosen to bias the base of Q2 at +4.3 volts.

Q1 and Q2 are each biased at 1 mA emitter current.

Rc2 is chosen to set the DC output voltage to zero volts.

Find Ree1, Rc1, Rc2

Ree1=__________________  Rc1=__________________  Rc2=__________________
Part b, 5 points

Find the mid-band value of $\frac{V_{out}}{V_{gen}}$.

$\frac{V_{out}}{V_{gen}} =$ __________________________
Part c, 10 points

Find Cpi of transistors Q1 and Q2. Give the frequency, in Hz (not rad/sec), of the 3 major poles in the transfer function.

Cpi1=___________________  Cpi2=___________________

fp1=___________________  fp2=___________________  fp3=___________________
Problem 2, 20 points

method of first-order time constants

A basic differential video amplifier is shown on the left. This circuit is fully differential, and so can be analyzed by the half-circuit method, where the connected emitters of the differential pairs become virtual grounds.

The circuit we therefore analyze is to the left. This is an AC equivalent circuit: It does not represent the DC.

All transistors have $f_t=500$ MHz and $C_{cb}=1$ pF.
Beta=\infty, V_D=\infty

$R_{gen}=R_b=50$ Ohms.

$Q_1$ and $Q_3$ are each biased at 1 mA. $Q_2$ and $Q_4$ are each biased at 2 mA.

$R_c=100$ Ohms

Part a, 5 points
Find Cpi of $Q_1$-$Q_4$.

$C_{pi1}=$
$C_{pi2}=$
$C_{pi3}=$
$C_{pi4}=$
Part b, 15 points
Using the method of time constants, find the dominant time constant \( a_1 \) of the transfer function \( V_{out}(s)/V_{gen}(s) \). Give the components of \( a_1 \) due to each transistor capacitance.

\[ a_1 = \frac{1}{15} \text{ seconds} \]

component of \( a_1 \) due to \( C_{cb1} = \frac{1}{20} \text{ seconds} \)

component of \( a_1 \) due to \( C_{cb2} = \frac{1}{25} \text{ seconds} \)

component of \( a_1 \) due to \( C_{cb3} = \frac{1}{30} \text{ seconds} \)

component of \( a_1 \) due to \( C_{cb4} = \frac{1}{35} \text{ seconds} \)

component of \( a_1 \) due to \( C_{pi1} = \frac{1}{40} \text{ seconds} \)

component of \( a_1 \) due to \( C_{pi2} = \frac{1}{45} \text{ seconds} \)

component of \( a_1 \) due to \( C_{pi3} = \frac{1}{50} \text{ seconds} \)

component of \( a_1 \) due to \( C_{pi4} = \frac{1}{55} \text{ seconds} \)
Problem 3, 20 points
method of first-order and second-order time constants

Q1 has $C_{be} = 10 \text{ pF}, C_{cb} = 1 \text{ pF}$. Beta=infinity, $V_a$=infinity.

Q1 has $C_{be} = 0 \text{ pF}, C_{cb} = 1 \text{ pF}$. Beta=infinity, $V_a$=infinity.

Cee1 and Cee2 are very large (AC short-circuits)

The supplies ($V_{cc}$ and $-V_{ee}$) are +/- 10 volts.
$I_{ee1} = 1 \text{ mA}, I_{ee2} = 2 \text{ mA}.$

$R_{gen} = R_{b1} = 50 \text{ Ohms}.$
$R_{c1} = 100 \text{ Ohms}, R_{c2} = 400 \text{ Ohms}.$

Use the method of time constants to find the frequencies of the first two poles of the transfer function $V_{out}(s)/V_{gen}(s)$.
The amplifier has a differential gain of $10^7$. R1=1 kOhm, R2=19 kOhm. The op-amp has infinite differential input impedance and zero differential output impedance.

The differential amplifier has poles in its open-loop transfer function at 20 Hz and 100 kHz.

Using the Bode plot below, determine the following:

Loop bandwidth=_________________  phase margin=_________________
Vout/Vgen at DC=_________________
The differential amplifier has infinite differential input impedance and zero output impedance. Its low-frequency gain is $10^6$, and it has a single pole in its transfer function at 2 Hz.

R1=100 Ohms. R2=9.9 kOhm. C=1.59 microfarads.

Part a, 5 points

Find the feedback factor $\beta(s)$, using standard form $\beta(s) = \frac{\beta_{dc}}{1 + a_1 s + a_2 s^2 + ...}$

$\beta(s) =$ ________________________
Part b, 10 points

Use the Bode plot below to plot the *closed loop transfer function* $A_{CL}$, the differential gain $A_d$, and the inverse of the feedback factor $1/\beta$. List all the poles and zero frequencies of $A_{CL}$.

Poles in $A_{CL}$ at frequencies __________________________________________ Hz

Zeros in $A_{CL}$ at frequencies __________________________________________ Hz
Problem 6 15 points

nodal analysis

Inductance, often present in the emitter lead of a common-emitter amplifier, can have a serious effect on high frequency response. Working from the small-signal equivalent circuit on the right, with $R_{gen}=0$ Ohms, $R_c=100$ Ohms, $L=1$ nH, $r_e=26$ Ohms, $C_{be}=1$ pF, $C_{cb}=0$ pF, beta=$\infty$, $V_a=\infty$, find $V_{out}/V_{gen}$ by nodal analysis. Give the answer in standard form

$$\frac{V_{out}(s)}{V_{gen}(s)} = \frac{V_{out}}{V_{gen}} \bigg|_{DC} \frac{1+b_1s+b_2s^2+...}{1+a_1s+a_2s^2+...}$$

$V_{out}(s)/V_{gen}(s)=$____________________________