ECE ECE145A (undergrad) and ECE218A (graduate)

Final Exam. Tuesday December 6, 2016 , 12 - 3 p.m.

Do not open exam until instructed to.
Open book. You have 3 hrs.
Use all reasonable approximations (5% accuracy is fine.) ,
AFTER STATING and justifying THEM.
Think before doing complex calculations. ***Sometimes there is an easier way.***

Problem	Points Received	Points Possible
1a		5
1b		7
1c		7 218A only
2a		5
2b		5
2c		5
2d		5
2e		5
2f		5
2G		10 218only
3a		8
3b		7
3c		5
3d		5
3e		5
4a		5
4b		7
4c		8
5a		5
5b		5
5c		10 218 only
total		

Name: __________________________

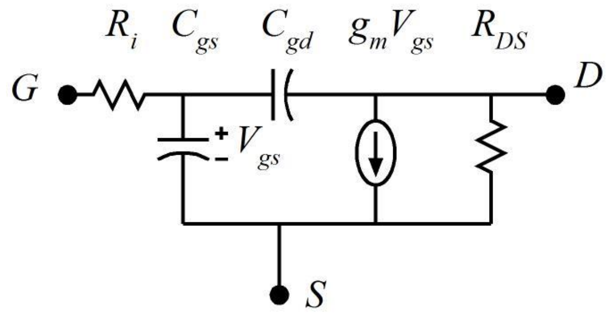
$$G_T = \frac{|S_{21}|^2 (1-|\Gamma_s|^2)(1-|\Gamma_L|^2)}{|(1-\Gamma_s S_{11})(1-\Gamma_L S_{22}) - S_{21}S_{12}\Gamma_s\Gamma_L|^2} \qquad G_P = \frac{1}{1-\|\Gamma_{in}\|^2}\cdot|S_{21}|^2\cdot\frac{1-|\Gamma_L|^2}{|1-\Gamma_L S_{22}|^2}$$

$$G_a = \frac{1-|\Gamma_S|^2}{|1-\Gamma_S S_{11}|^2}\cdot|S_{21}|^2\cdot\frac{1}{1-\|\Gamma_{out}\|^2} \qquad G_{\max} = \frac{|S_{21}|}{|S_{12}|}\cdot\left[K-\sqrt{K^2-1}\right]\text{if } K>1$$

$$G_{MS} = \frac{|S_{21}|}{|S_{12}|}\cdot\text{if } K<1 \qquad K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2}{2|S_{21}S_{12}|} \quad \text{where } \Delta=\det[S]$$

Unconditionally stable if : (1) K>1 **and** (2) $\|\det[S]\|<1$

Problem 1, 12 points (145A), 19 points (218A)
Transistor two-port properties, Gain relationships

Device model: $g_m = 1mS/\mu m \cdot W_g \quad R_i = 1/g_m$ $C_{gd} = 0.0 fF/\mu m \cdot W_g$ $C_{gs} = 0.5 fF/\mu m \cdot W_g$ $G_{ds} = 0.1mS/\mu m \cdot W_g$ $W_g = 10\mu m$	

part a, 5 points

You are going to use the transistors at 100 GHz signal frequency.
What power gain would you exect to get after impedance, matching ?
What would be the correct generator impedance and load impedance to obtain this power gain ?

Gain = _______________ dB
Source impedance = ________________ Ohms
Load impedance = _________________ Ohms

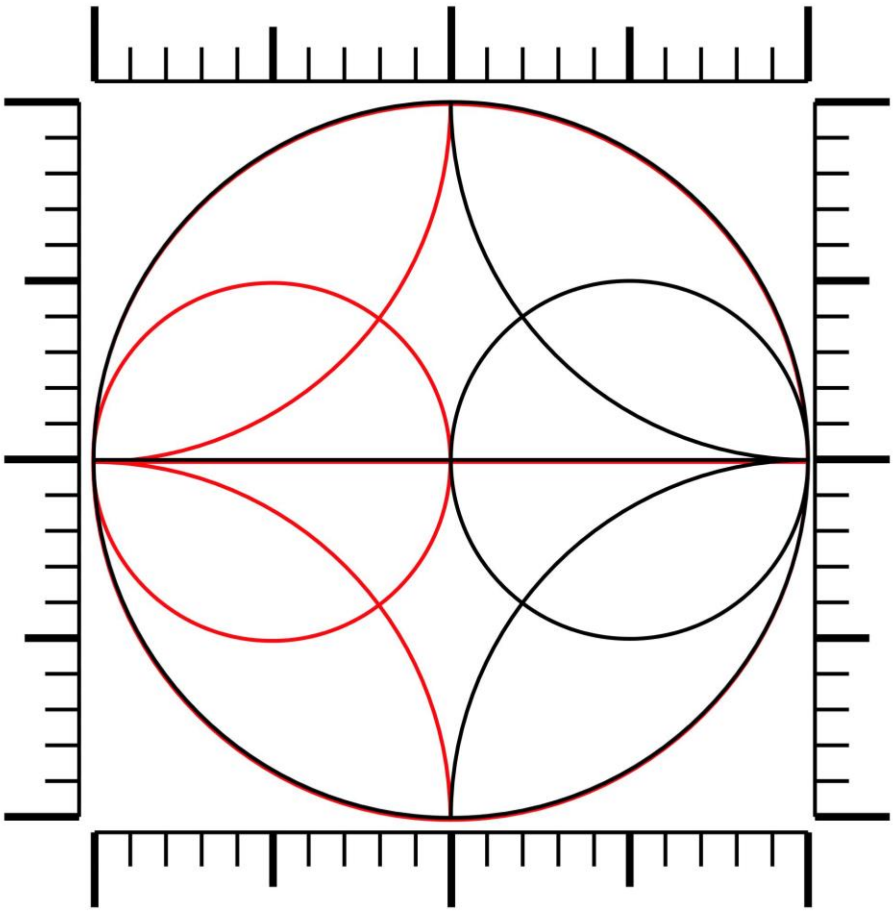
part b, 7 points

Find the short-circuit current gain, in dB, at 100 GHz

H21= ______________ dB

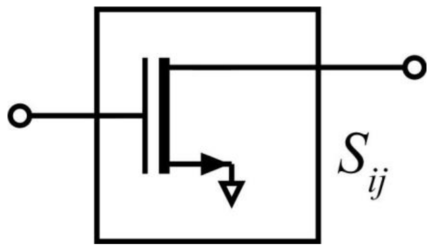
part b, 7 points (218A students only)

With the numerical values given in the equivalent circuit, make clear sketches of S11, S22, S12, and S21, from DC to infinite frequency, on the Smith chart below. This may require that you calculate the S parameters first.



Problem 2, 30 points (145A), 40 points (218A)

Two-port properties, Power gain definitions

At a signal frequency of 5 GHz, a transistor has $S_{11} = 1/2$, $S_{12} = 1/20$, $S_{21} = 2$ and $S_{22} = 0$, as defined with a 50 Ohm impedance reference.	

part a, 5 points

Write an expression for Γ_{in} in terms of Γ_L. Based upon this, is the circuit unconditionally stable ?

$\Gamma_{in} =$________________________________

part b, 5 points

If the transistor, were directly connected (but with bias decoupling…) to a 50 Ohm load, and a 50 Ohm generator with 1 mW available power, what would be the power dissipated in the load ?

part c, 5 points

If you were to first stabilize (if necessary) and then impedance match the input and output to 50 Ohms, what would be the gain S_{21} of the resulting amplifier ?

part d, 5 points

If you were to load the transistor with 100 Ohms, and then impedance-match the input to a generator with 1 mW available source power, what would be the power in the load ?

part e, 5 points

If you were to take the transistor connect the input directly to a 100 Ohm generator with 1 mW available source power, and then impedance-match the output to a load, what would be the power in the load ?

part f, 5 points

If you were to take the transistor and connect the transistor to a 100 Ohm generator, of 1 mW available power, and a 100 Ohm load, what would be the power in the load.

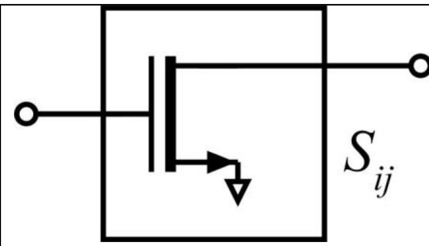
part g, 10 points (tricky, ece218c students only)

If were to take the transistor and to impedance match both input and output to *100* Ohms, then please can you give the (50 Ohm normalized) values of the following:

S11=____________ S22=______________________ |S21|=_____________________

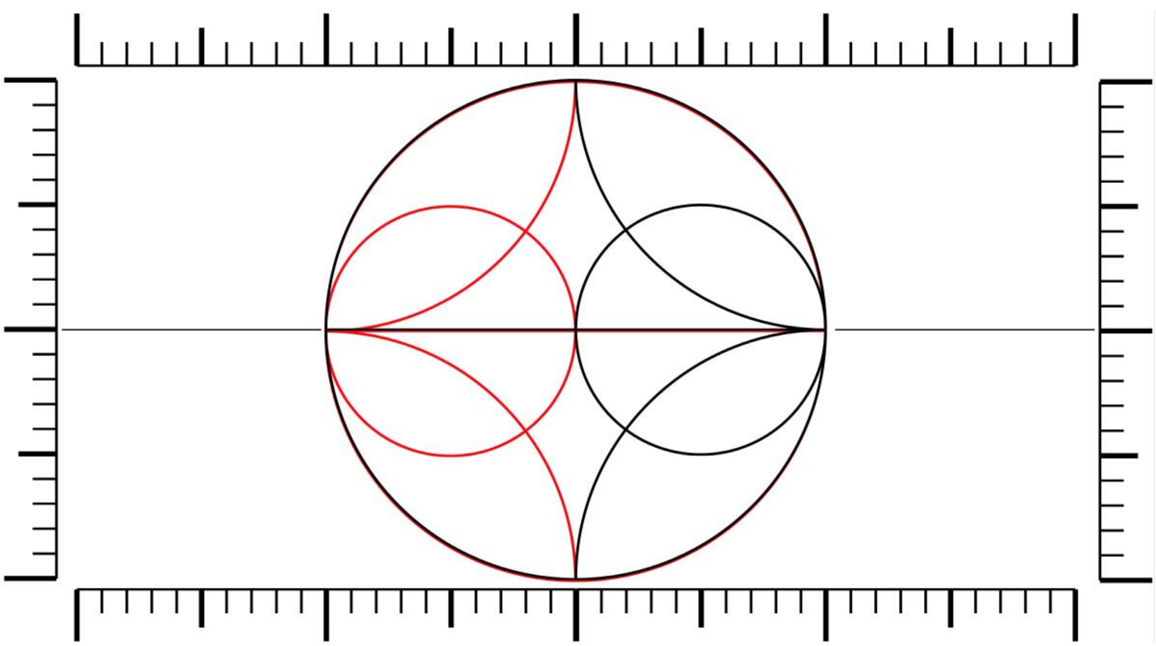
Problem 3, 30 points

Potentially unstable amplifier design, gain circles

At 50GHz, a transistor has S11=0, S12=1/10, S21=5, S22=3/4. These S-parameters are normalized to a 50 Ohm reference impedance	

part a, 8 points

Draw the *source* stability circle on the graph below:
(to do this perfectly, you would need a compass: you can sketch most of the curve, but be sure to plot *exactly* the points where the stability circle crosses the real axis, i.e. the x-axis.)



part b, 7 points

Continuing with part A above, you must add either a parallel or a series resistance on the *input* to make the device unconditionally stable. ***Only one of the two choices will work***. Should you use a parallel or a series element ? What value should you use ?

Parallel or series ? ________________________

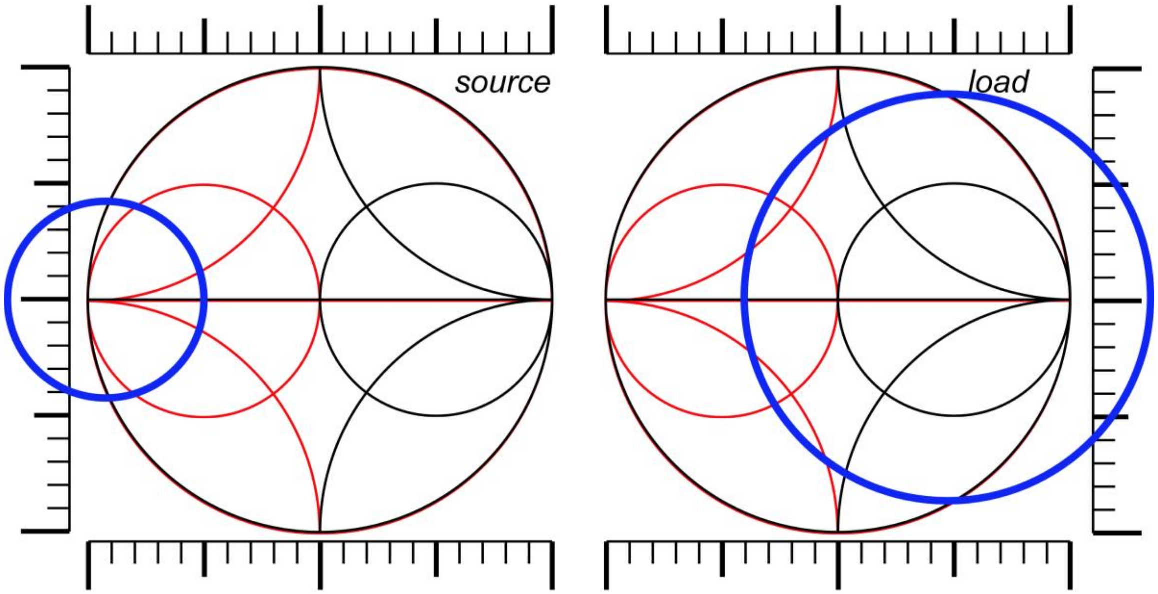
R=___________________

part c, 5 points

Continuing with part A above, after stabilization, if we then impedance-match on input and output, what will be the resulting power gain ?

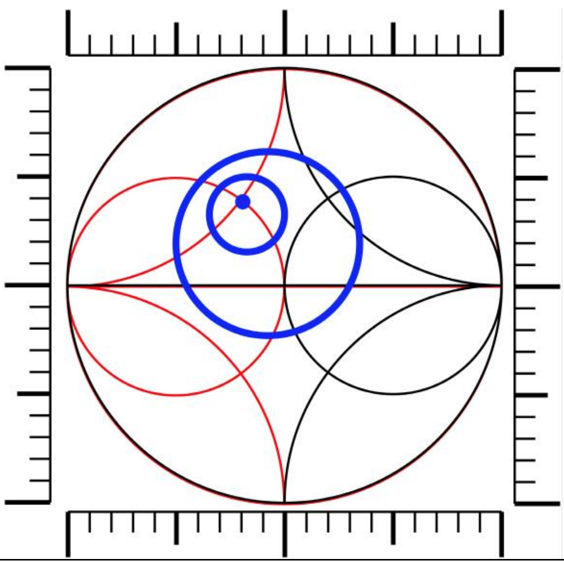
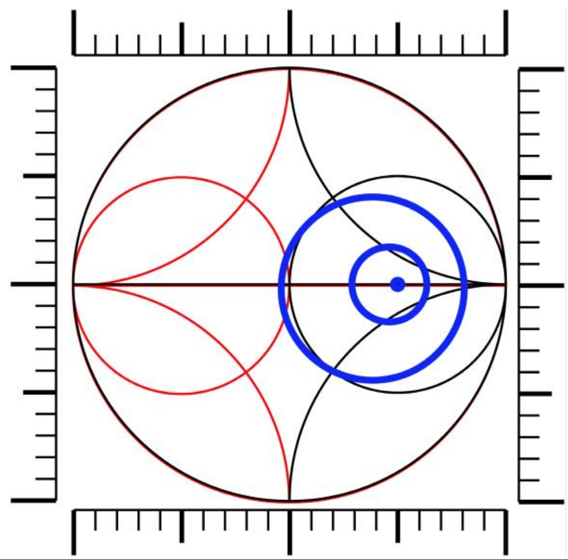
Power gain = ______________________

part d, 5 points



A MOSFET in common-source mode has $\|\|S_{11}\|\|$ and $\|\|S_{22}\|\|$ both less than 1. Source and load stability circles are as shown. The Smith charts use 50 Ohms impedance normalization. Draw **2*** circuit diagrams, giving resistor values, of methods of stabilizing the transistor. ***Please draw your answers in the 3 boxes to the right and below***	
circuit #1	circuit #2

part e, 5 points

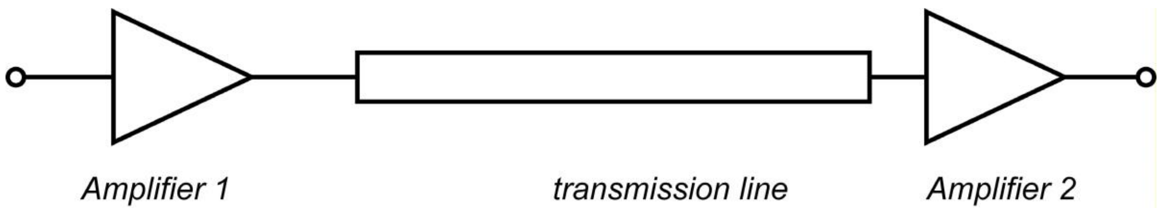
Available gain circles	Operating gain circles
	

A FET in common-source mode has operating and available gain circles as shown. Find the optimum generator and load impedances (in complex Ohms).

optimum source impedance= ___________________________

optimum load impedance= ___________________________

Problem 4, 20 points
S parameters and Signal flow graphs



Amplifier 1 has S-parameters S_{ij}^{1}, amplifier2 has S-parameters S_{ij}^{2}. Between is a *50* Ohm transmission-line of *exactly* one-quarter wavelenght at the design frequency.

part a, 5 points

Compute the S-parameters S_{ij}^{line} of the transmission line

part b, 7 points

Draw a signal flow graph of the overall system. Be intelligent about this.

part c, 8 points

Using Mason's gain relationship, find S11 of the overal system.

Problem 5, 10 points (145A), 20 points (218A)
Power amplifier design

part a, 5 points

In the Teledyne InP HBT technology, the maximum current per unit emitter *length* is 3 mA per micron of length. For wide bandwidth, the maximum emitter stripe length is 4 microns. The breakdown voltage is 3.5V, and the minimum (knee) voltage is 1.0 Volts.

What is the maximum RF power per 4 micron emitter finger ? ____________________

If the minimum impedance we could tune to were 10 Ohms, how many emitter fingers would we use in the power transistor, so that the required load impedance were 10 Ohms? ___________________

What output power would that cell produce ? ____________________

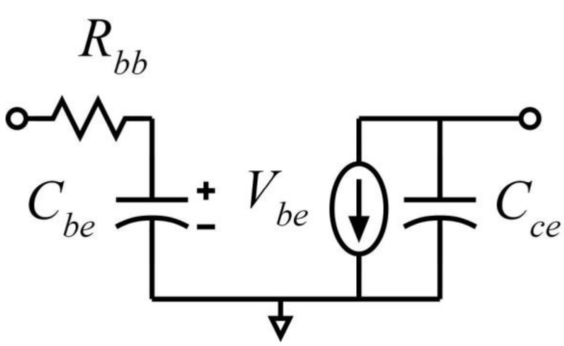
part b, 5 points

For the above amplifier, what would be the collector efficiency ?

part c, 10 points (218A students only)

The (somewhat contrived) device model is to the right, with $g_m = qI_{DC}/kT$
$R_{bb} = 20\Omega - \mu m / L_E \quad C_{be} = g_m \tau_f$, where
$\tau_f = 0.32$ ps, and $C_{CE} = zero$

The signal frequency is 340 GHz.



What would the the DC bias current IDC ? ______________________

Give the values of Rbb ______________ , Cbe_________________ and gm__________

What is the amplifier power gain at 340 GHz ? __________________________

What is the amplifier power-added efficiency ? __________________________