

# ECE 137 A Mid-Term Exam

Thursday February 5, 2015

Do not open exam until instructed to.

Closed book: Crib sheet and 1 page personal notes permitted

There are 3 problems on this exam, and you have 75 minutes.

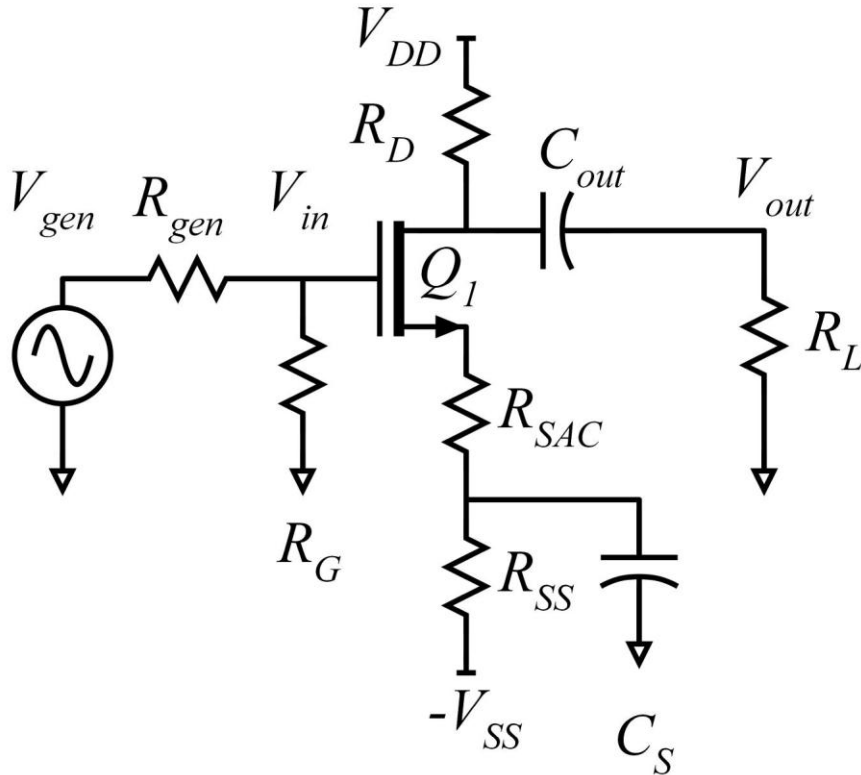
Use any and all reasonable approximations (5% accuracy is fine. ),  
***AFTER STATING and approximately Justifying them.***

Name: \_\_\_\_\_

Part	Points Received	Points Possible	Part	Points Received	Points Possible
1a		10	2f		15
1b		5	3a		8
1c		5	3b		8
1d		10	3c		4
1e		15			
2a		10			
2b		5			
2c		5			
2d		10			
2e		5			
<b>TOTAL</b>					100

**Problem 1, 30 points**

You will be working on the circuit below:



The transistor has

$$L_g = 45 \text{ nm}, \quad \mu = 400 \text{ cm}^2/\text{V} \cdot \text{s}, \quad \epsilon_{r,ox} = 3.8, \quad T_{ox} = 1 \text{ nm}, \quad v_{sat} = 10^7 \text{ cm/s}, \quad V_{th} = 0.284 \text{ V},$$

$$1/\lambda = 10 \text{ V},$$

From which we calculate:

$$c_{ox} v_{sat} = 3.36 \text{ mA/V}/\mu\text{m}, \quad \mu c_{ox} / 2L_g = 15 \text{ mA/V}^2/\mu\text{m}, \quad \Delta V = L_g v_{th} / \mu = 0.113 \text{ V},$$

The supplies are +1V and -1 V

You are to bias the transistor at 2mA drain current,  
with 0.6V DC drain voltage, and with -0.45 V DC source voltage.

$$R_{SAC} = 20 \Omega, \quad R_G = 1 \text{ M}\Omega, \quad R_{gen} = 75 \text{ k}\Omega, \quad R_L = 10 \text{ k}\Omega$$

$C_S$  and  $C_{out}$  are very large (AC short-circuit)

Part a, 10 points

DC bias.

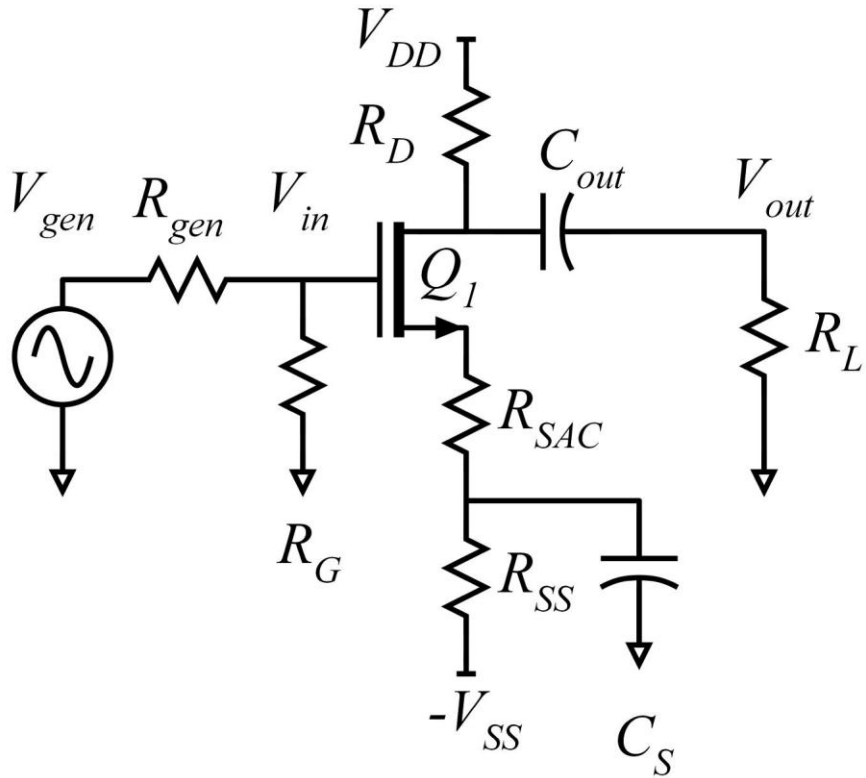
Use this approximation: Ignore (i.e. set to zero) the FET  $\lambda$  parameter in the DC bias calculation.

Find the following:

FET gate width  $W_g$ =\_\_\_\_\_  $R_{ss}$ =\_\_\_\_\_  $R_D$ =\_\_\_\_\_

Part b, 5 points

DC bias



On the circuit diagram above, label the DC voltages at **ALL nodes** and the DC currents through **ALL resistors**

Part c, 5 points

Using the actual (nonzero) FET  $\lambda$  parameter, find the FET small signal parameters  
gm=\_\_\_\_\_ Rds=\_\_\_\_\_

Part d, 10 points.

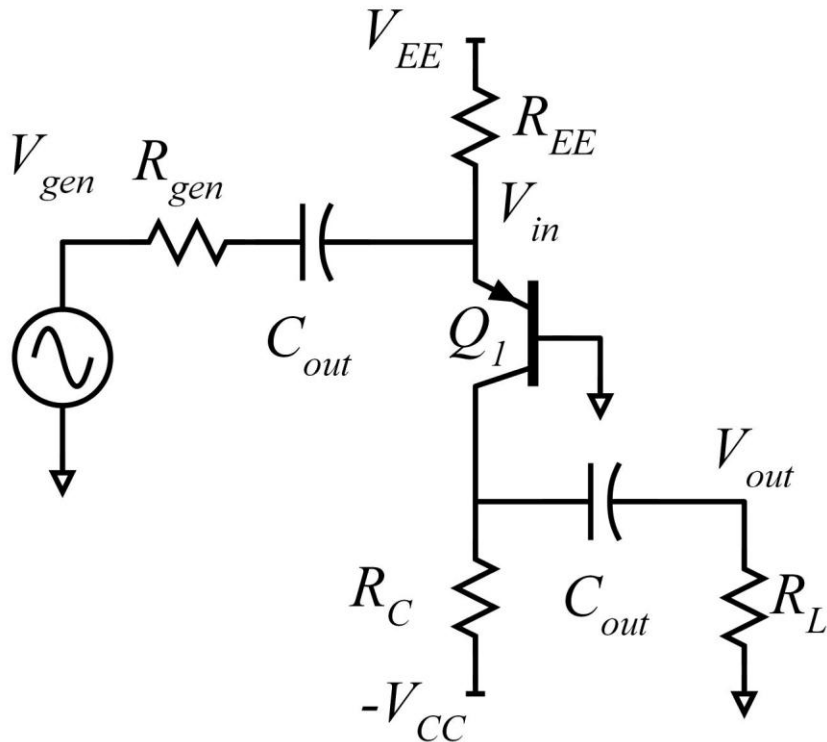
Find the small signal voltage gain  $V_{out}/V_{in}$  and the amplifier small-signal input resistance.

$V_{out}/V_{in} =$  \_\_\_\_\_

$R_{in, \text{ amplifier}} =$  \_\_\_\_\_

**Problem 2, 50 points**

You will be working on the circuit below:



Q1:  $\beta = 100$ ,  $V_A = \text{infinity V}$

The supplies are +5V and -5 V.

You will bias the transistor with 2mA collector current.

The DC collector bias voltage is -2.5V.

$R_L$  is 10 k $\Omega$ ,  $R_{gen}$  is 100  $\Omega$

Part a, 10 points

DC bias.

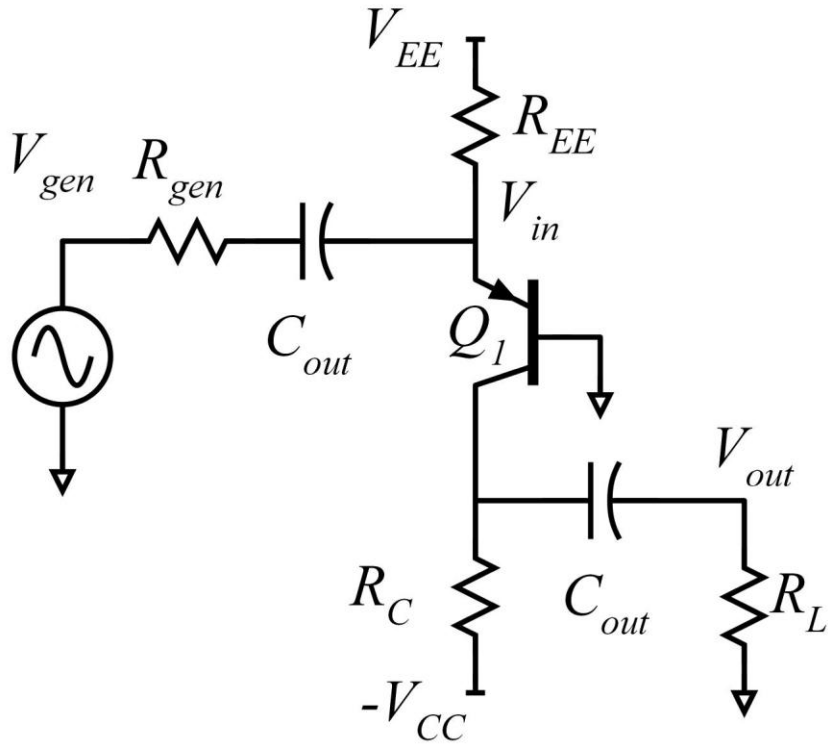
Find the following:

$$R_{EE} = \underline{\hspace{2cm}} \quad R_C = \underline{\hspace{2cm}}$$



Part b, 5 points

DC bias



On the circuit diagram above, label the DC voltages at **ALL nodes** and the DC currents through **ALL resistors**

Part c, 5 points

Find the small signal parameters of Q1.

$g_m = \underline{\hspace{2cm}}$        $R_{ce} = \underline{\hspace{2cm}}$        $R_{be} = \underline{\hspace{2cm}}$

Part d, 10 points.

Find the small signal voltage gain ( $V_{out}/V_{in}$ ) of Q1 and the amplifier small-signal input resistance.

$V_{out}/V_{in} =$  \_\_\_\_\_

$R_{in,amp} =$  \_\_\_\_\_

Part e, 5 points

Find  $(V_{in}/V_{gen})$  and  $(V_{out}/V_{gen})$

$(V_{in}/V_{gen}) =$  \_\_\_\_\_

$(V_{out}/V_{gen}) =$  \_\_\_\_\_

Part f, 15 points

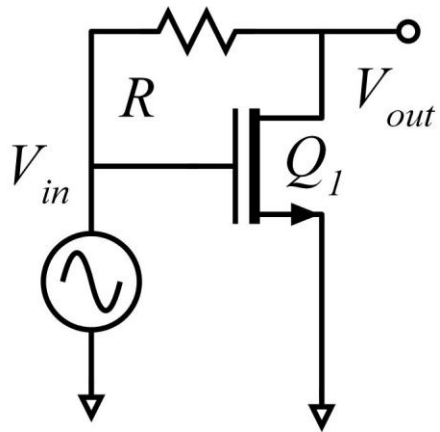
Now you must find the maximum signal swings. Find the output voltage due to saturation and cutoff in Q2. **Give the sign (+ or -) in your answers below.**

Cutoff of Q1; Maximum  $\Delta V_{out}$  resulting = \_\_\_\_\_

Saturation of Q1; Maximum  $\Delta V_{out}$  resulting = \_\_\_\_\_

**Problem 3, 20 points**

*nodal analysis*



You will be working on the circuit to the left.

Ignore DC bias analysis. You don't need it.

Transistor 1 has transconductance  $g_{m1}$ .

The drain-source resistance  $R_{ds}$  of the transistor is infinity (so you don't need to draw it!)

Part a, 8 points

Draw the small-signal equivalent circuit

Part b, 8 points

Find, by nodal analysis, a small-signal expression for  $V_{out}/V_{in}$ .

$V_{out}/V_{in} =$  \_\_\_\_\_

Part c, 4 points

$g_{m1} = 1 \text{ mS}$  ,  $R = 3\text{k}\Omega$

Give a numerical value for  $V_{out}/V_{in}$ .

$V_{out}/V_{in} = \underline{\hspace{2cm}}$