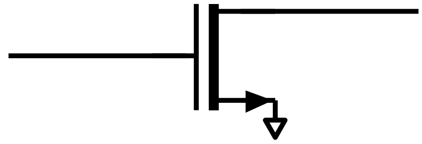
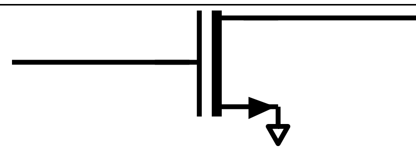
ECE2c Problem set #2:

Problem 1: Consider a mobility-limited FET, ie. $I_d = (\mu C_{ox} W_g / 2L_g)(V_{gs} - V_{th})^2 (1 + \lambda V_{ds})$ where $(\mu C_{ox} W_g / 2L_g) = 1\ \text{mA}/\text{V}^2$, V_{th} =0.3 V, and λ =0.1 V^{-1}. (a) If the device is biased with 2 Volts Vds and 0.5 mA drain current, find the transconductance and output conductance



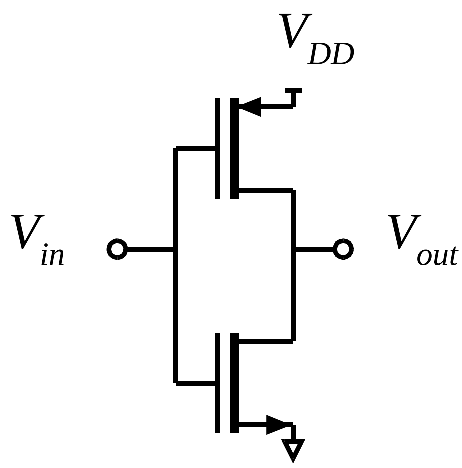
(b) draw a small-signal equivalent circuit at this bias.

Problem 2: The MOSFET has a +0.3 Volt threshold voltage and $v_{sat} C_{ox} W_g$ =0.5 mA/V (assume velocity-limited characteristics, i.e. $I_d = v_{sat} C_{ox} W_g (V_{gs} - V_{th})(1 + \lambda V_{ds}))$, where we will assume λ =0.1 V^{-1}. (a) If the device is biased with 1 Volts Vds and Vgs=0.5 Volts, find the transconductance and output conductance



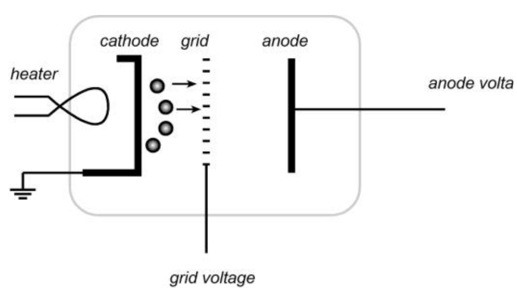
(b) draw a small-signal equivalent circuit at this bias.

Problem 3: This is a common-source amplifier
a) Use velocity-limited models.
Thresholds are +/- 0.4 V for the NMOS and PMOS FETs. λ =0.3 V^{-1}, the gate length is 45 nm, and the oxide thickness 0.8 nm. The NMOS FET has v_{sat} =10^7 cm/s; the value for the PMOSFET is half this. The NMOS FET has 5 microns gate width, the PMOS FET 10 microns. Vdd is 1.6 Volt. The input has 0.75 V DC bias, to which a small-signal input voltage is added.
(b) Compute the DC values of Vout and drain current.
(c) Compute the small signal equivalent circuit for each transistor, and find the following small signal transistor parameters: gm, Rds for each.

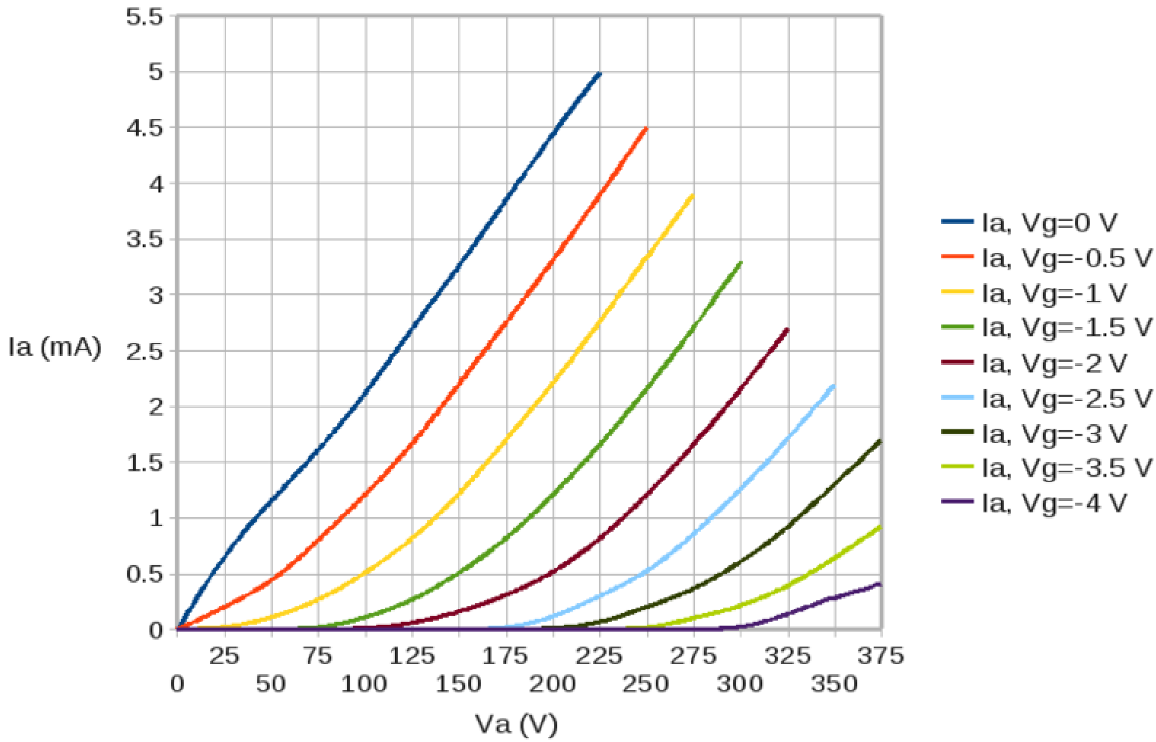


(d) draw the small-signal equivalent circuit of the amplifier
(e) If a small AC voltage is added to the 0.75 V DC input voltage, find the ac small signal voltage Vout.

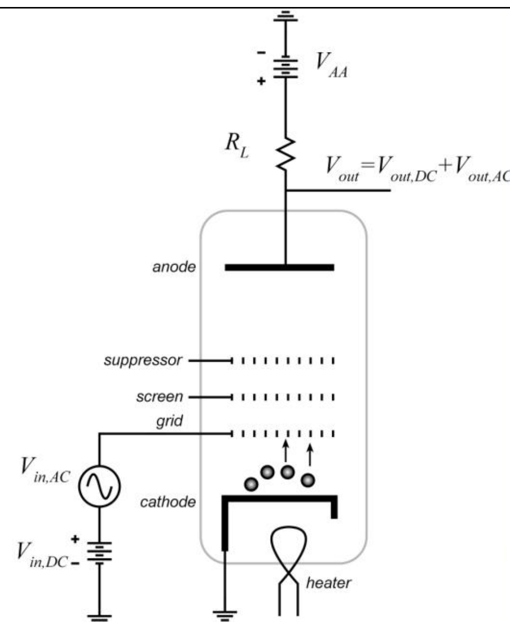
Problem 4: meaning of small signal parameters. A triode vacuum tube is shown to the right. Typical IV characteristics are also shown...Va is the anode voltage and Vg is the Grid voltage. A tube's grid current is nearly zero as long as the grid is more negative than the cathode, and the anode current is given by $I_a = k_p (V_g + V_a / \mu)^{3/2}$



where μ is known as the amplification factor and k_p is a characteristic of the tube having units of amps per volt^3/2. (a) Defining the output conductance as $\partial I_a / \partial V_a$ and the transconductance as $\partial I_a / \partial V_g$, derive expressions for these. (b) Working with the characteristics above, compute numerical values of the transconductance and output conductance at Va=200 V and Vg= -0.5 Volts

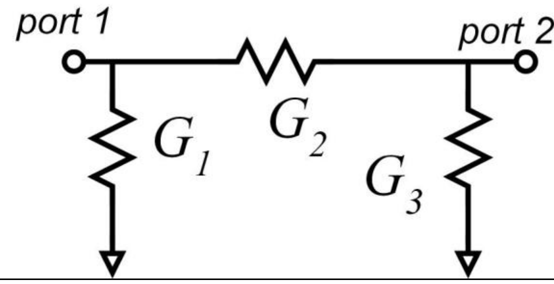


Problem 5: Taking the same tube as in problem 4b, $V_{in,DC}$=-0.5 Volts, V_{AA}=232 Volts, R_L=10 kOhms, and V_{inAC} = 1 mV$\cdot\cos(2\pi\cdot 1\text{kHz}\cdot t)$. (a) Using your work from problem 4, find a small-signal equivalent 2-port small-signal representation of the tube. Give values for all elements. (b) Redraw the circuit diagram to the right with the transistor replaced by its 2-port small-signal representation. At this point, you should remove the batteries $V_{in,DC}$ and V_{AA} to the diagram, as they have no AC Fourier component. (c) Analyze the circuit to find the AC signal $V_{out,AC}$



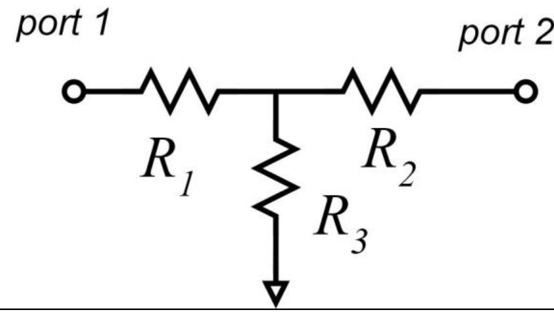
Problem 6: (a) Compute the 2-port Y parameters of the circuit (b) Compute the Z parameters.

G1=3 mS, G2=2 mS, G3=1 mS.



Problem 7: (a) Compute the 2-port Y parameters of the circuit (b) Compute the Z parameters.

R1= 3kOhm, R2=2 kOhm, R3=1kOhm



Problem 8: At a signal frequency of 2 GHz, find the Y parameters

C1= 2 pF
C2=3 pF
L=2 nH