FINAL EXAM

EE315 Spring 2017—Dr. B

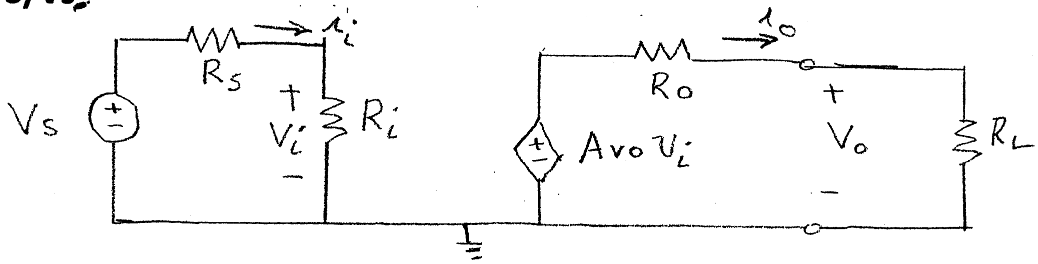
NAME Solution Key

DO ALL YOUR WORK ON THIS EXAM. USE THE BACK SIDES of EXAM PAPER IF NECESSARY BUT POINT ME WHERE YOU DID THAT.

- ***Your Equation "Cheat Sheet" must be turned in with the Exam.***
- ***NO Cell PHONE Calculators allowed. Other calculators ok.***
- ***Closed books/closed lecture notes.***
- ***<u>Each Problem worth 10 points.</u>***

Why then, can one desire too much of a good thing? WILLIAM SHAKESPEARE, *As You Like It*

Problem 1: **For the circuit model of voltage amplifier below, Avo = 100 volts/volt when Ri = 10Rs and RL = 10 Ro. Compute the OVERALL VOLTAGE GAIN Vo/Vs.**



$$V_i = \left(\frac{R_i}{R_i + R_s}\right) V_s = \left(\frac{10 R_s}{11 R_s}\right) V_s = \frac{10}{11} V_s$$

$$V_o = \left(\frac{R_L}{R_o + R_L}\right) 100 V_i = \left(\frac{10 R_o}{11 R_o}\right) 100 V_i$$

SOURCE p. 26 Textbook

$$V_o = \left(\frac{10}{11}\right) 100 V_i = \frac{10}{11}(100)\left(\frac{10}{11}\right) V_s$$

$$\frac{V_o}{V_s} = \frac{(100)(100)}{(11)(11)} = \boxed{82.64 \text{ volt/volt}}$$

2. Find the complex impedance at 10 K hertz for: (nano is 10 to -9 power, pico is 10 to -12 power. Leave answer in form of Z = real part + imaginary part.

(a) a 1 K ohm resistor in series with a 10 nano-farad capacitor.

(b) a 10 K ohm resistor in series with a 100 millihenry inductor.

(a) $$Z = 1000 - \frac{j}{\omega C} = 1000 - \frac{j}{2\pi(10 \times 10^{3})(10 \times 10^{-9})}$$

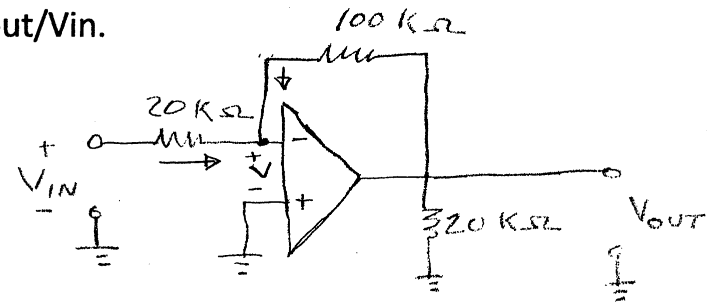
$$= 1000 - \frac{j}{6.2832 \times 10^{-4}}$$

$$\boxed{Z = 1000 - j\,1591.54\ \Omega}$$

(b) $$Z = 1000 + j(2\pi)(100 \times 10^{-3}) = 1000 + j\,.6283\ \Omega$$

$$\boxed{Z = 10000 + j\,.6283\ \Omega}$$

3. Assuming the op amp is ideal, derive an expression for voltage gain the amplifier, Vout/Vin.



SOURCE
HW Prob. 2.8
p 117, textbook

$$\frac{V_{IN}-V}{20K} + \frac{V_{OUT}-V}{100K} = 0$$

but $V=0$ because ideal op Amplifier

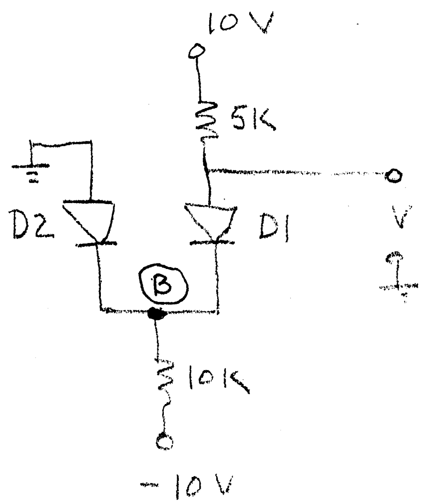
$$\frac{V_{IN}}{20K} + \frac{V_{OUT}}{100K} = 0$$

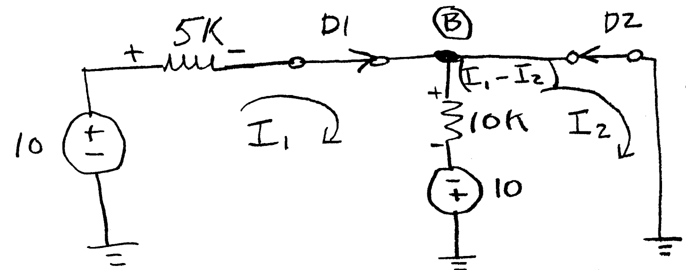
$$\frac{V_{OUT}}{100K} = -\frac{V_{in}}{20K} \Rightarrow \frac{V_{OUT}}{V_{in}} = -\frac{100K}{20K} = -5 \text{ V/V}$$

$$\boxed{\frac{V_{OUT}}{V_{in}} = -5 \text{ V/V}}$$

SOURCE: Example 4.2
Textbook,
p. 181

4. My EE friend who graduated from Loachapoka University says both diodes in the circuit below are forward biased. Is my friend correct? No CREDIT FOR Guessing





D1 & D2
MARKED
FOR FB.

$$10 - 5K\, I_1 - 10K(I_1 - I_2) + 10 = 0$$

$$\boxed{-15K\, I_1 + 10K\, I_2 = -20}$$

$$-10 + 10K(I_1 - I_2) = 0$$

$$-10 + 10K\, I_1 - 10K\, I_2 = 0$$

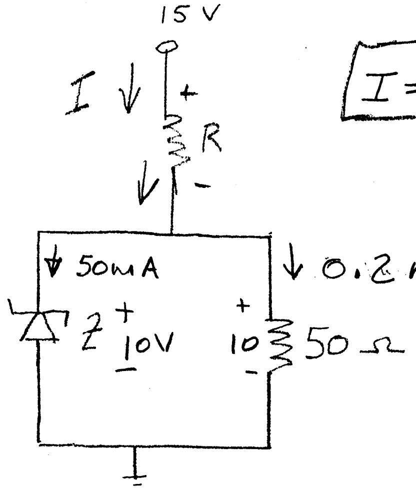
$$\boxed{10K\, I_1 - 10K\, I_2 = 10}$$

$$I_2 = \frac{\begin{vmatrix} -15K & -20 \\ 10K & +10 \end{vmatrix}}{\begin{vmatrix} -15K & +10K \\ 10K & -10K \end{vmatrix}} = \frac{-150K + 200K}{150\times10^6 - 100\times10^6} = \frac{50K}{50\times10^6} = 1\text{ mA}$$

$\Rightarrow$ SAYS current thru RB D2.

$\boxed{\text{EE is incorrect}}$

5. Consider the Zener Shunt Regulator below. Vz = 10 volts with Iz = 50 Milliamps through the Zener. The load resistor is 50 ohms and the supply voltage is 15 volts. What is the value of R, assuming the Zener is ideal, and what is the total current supplied by the Voltage source?



$\boxed{I = .2 + 50\ mA = 250\ mA}$

KVL $10 + R(.250) - 15 = 0$

$R(.250) = 5$

$\boxed{R = 20\ \Omega}$

6. A semiconductor diode normally having a forward voltage drop of 0.7 volts at 1.0 milliamp is operated at 0.5 volts. What is the resulting value of current through the diode? • BOLTZMAN'S Constant = 1.3×10^{-23} Joules/°Kelvin

• Charge on electron = 1.6×10^{-19} Coulomb

• T in degrees Kelvin Assume 300° K

SOURCE HW Prob. 4.19 p. 234

$I_D = I_S e^{V_D/V_T}$

$V_T = \frac{kT}{q} = \frac{1.3 \times 10^{-23}(300)}{1.6 \times 10^{-19}} = .0243$ volts ⇒ Textbook Uses .025 volts here

$.001 = I_S e^{.7/.0243} = I_S(3.24 \times 10^{12})$

$I_S = 3.086 \times 10^{-16}$ Amp

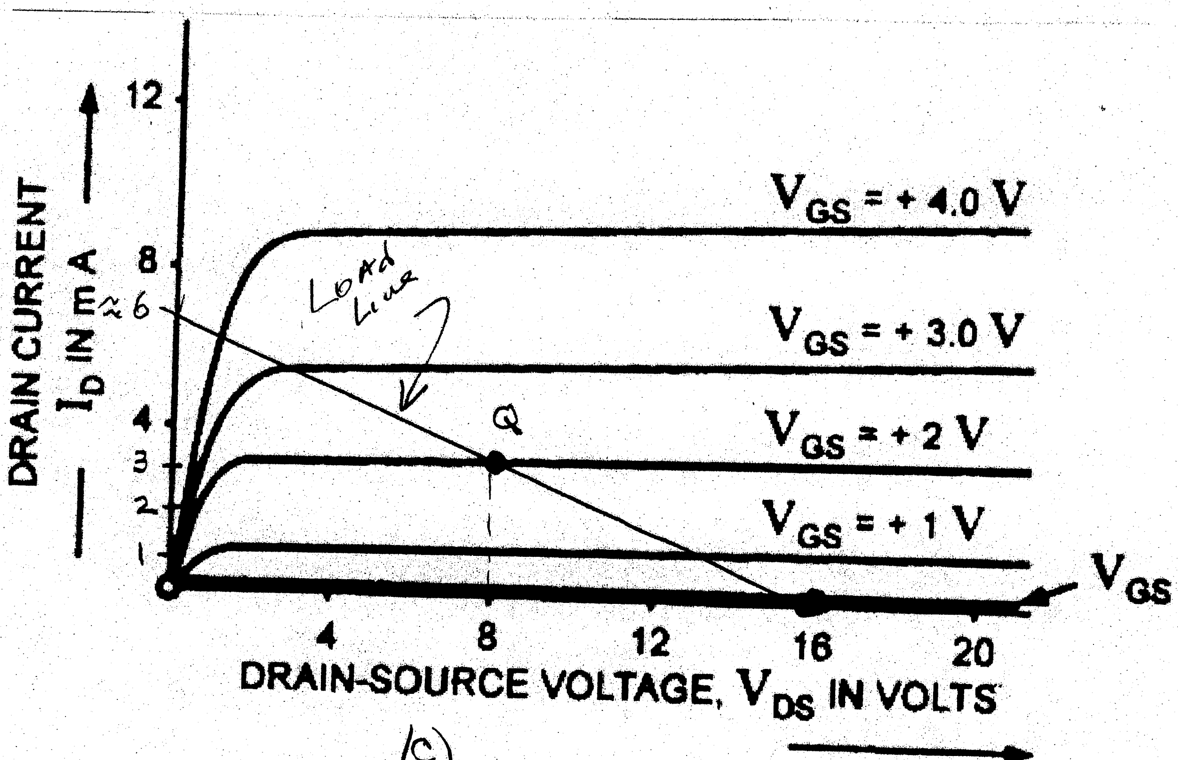
then $I_D = 3.086 \times 10^{-16} \left(e^{.5/.0243}\right) = \boxed{2.66 \times 10^{-7} \text{ Amp}}$

7. The operational characteristics for an nMOSFET device are shown below as well as a desired Q point for operating this device in the circuit below.

(a) from the circuit,derive the equation for the load line relating Id and Vds.

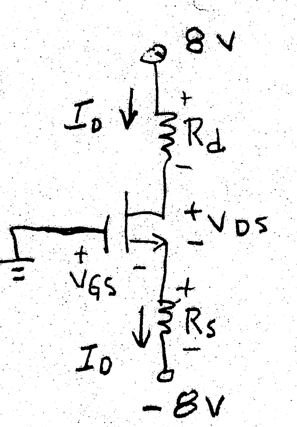
(b) What is the slope of the Load Line? AND DRAW IT ON THE FIGURE BELOW.

(c) Compute values for resistors Rd and Rs that will "set" the device Q point as shown.



(c)

NOTE: Q point is at $V_{GS} = 2$, $V_{DS} = 8$, $I_D = 3$ mA



KVL: $-8 + R_S I_D + V_{GS} = 0$

$-8 + R_S(.003) + 2 = 0 \Rightarrow \boxed{R_S = \frac{6}{.003} = 2K}$

KVL $-8 + R_S I_D + V_{DS} + R_d I_D - 8 = 0$ ← Load line Equation

$-8 + 2000(.003) + 8 + R_d(.003) - 8 = 0$

$-8 + 6 + 8 + .003 R_d - 8 = 0$

$.003 R_d = 2$

$R_d = 2/.003$

$\boxed{R_d = 666.7\,\Omega}$

(a) $(R_S + R_d) I_D + V_{DS} = 16$

$\boxed{I_D = \frac{16 - V_{DS}}{R_S + R_d} = \frac{16 - V_{DS}}{2666.7}}$

When $I_D = 0$ $V_{DS} = 16$ V

(b) Slope $= \frac{1}{2666.7} = 3.75 \times 10^{-4}$

8. Given an nMOSFET device. Find Drain current , Id, when:

Epsilon ox = 3.45 x 10 (-11 power) Farads/meter

SOURCE
HW Problem 5.14(c)

tox = 6 nanometers

Mu sub n = 460 cm ~~squared~~ / volt . sec

Vt= 0.5 volts

W/L = 10

Vgs = 2.5 volts and Vds = 0.2 volts

First Test Region of operation.

$V_{DS} \geq V_{GS} - V_t$ in Sat.

is $.2 \geq 2.5 - .5$

is $.2 \geq 2$ $\boxed{\text{No - Triode Region}}$

Triode Region

$$I_D = k_n' \frac{W}{L}\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$$k_n' = \mu_n C_{ox} = \mu_n \frac{\epsilon_{ox}}{t_{ox}} = \left[460 \frac{cm^2}{V.sec}\right]\left[\frac{3.45 \times 10^{-11} \frac{F}{m}}{6 \times 10^{-9}\ m}\right]$$

$$= \frac{460\ cm^2}{volt.sec} \times 5.75 \times 10^{-3} \frac{F}{m^2} = 2.645 \frac{cm^2}{m^2} \frac{Farad}{volt.sec}$$

$$= 2.645\left[\frac{cm^2}{1 \times 10^4\ cm^2}\right]\left[\frac{\frac{Amp.sec}{volt}}{volt.sec}\right] = 2.645 \times 10^{-4} \frac{Amp}{V^2}$$

$$I_D = 2.645 \times 10^{-4}(10)\left[(2.5 - .5)(.2) - \frac{1}{2}(.2)^2\right]$$

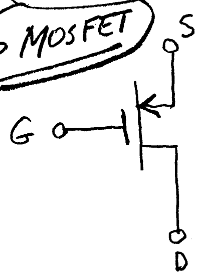
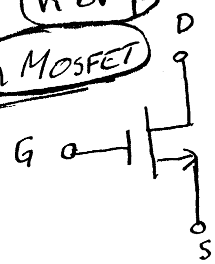
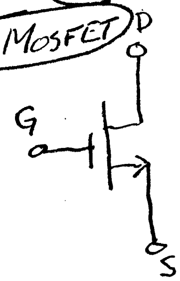
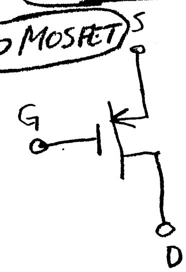
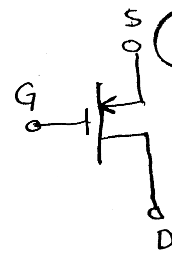
$$= 2.645 \times 10^{-3}[.4 - .02]$$

$$= 2.645 \times 10^{-3}[.38]$$

$$\boxed{I_D = 1\ mA}$$

9. (a) Which are pMOSFETS and which are nMOSFET devices?

(b) what is the region of operation (triode, saturation, or boundary for each device given the data shown?

n or p ?	n or p ?	n or p ?	n or p ?	n or p ?
p MOSFET	n MOSFET	n MOSFET	p MOSFET	p MOSFET
				
V_{ov} = 2 volts	V_{ov} = 3 volts	V_{GS} = 2 volts	V_{ov} = 2 volts	V_{ov} = 2 volts
V_{SD} = 4 volts	V_{DS} = 3.5 volts	V_{tn} = 0.5 volts	V_{SD} = 1.5 volts	V_{SD} = 2 volts
S $V_{SD} \geq V_{ov}$	Is $V_{DS} \geq V_{ov}$ yes	V_{DS} = 1 volt Is $V_{DS} \geq V_{ov}$ No	Is $V_{SD} \geq V_{ov}$? No	Is $V_{SD} \geq V_{ov}$ = Boundary
REGION?	REGION?	REGION?	REGION?	~~REGION?~~
SATURATION	SATURATION	Triode	Triode	Boundary Region

10. Given an nMOSFET device where:

kn(primed)= 400 microamps/Volt (squared)

Threshold voltage = 0.5 volts

Vgs = Vds = Vsupply = 1.8 volts

Drain current Id = 2milliamps

L = 0.18 micrometers

Source
HW Problem 5.20,
page 295

FIND W

Determine Region of Operation: Is $V_{DS} \geq V_{GS} - V_t$
$1.8 \geq 1.8 - .5$
yes SATURATION

$$i_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2$$

$$.002 = \frac{1}{2}\left[400 \times 10^{-6} \frac{\text{Amps}}{V^2}\right]\left[\frac{W}{.18 \times 10^{-6}}\right]\left[1.8 - .5\right]^2 V^2$$

$$.002 = \frac{200 \times 10^{-6}}{.18 \times 10^{-6}} (1.3)^2 W$$

$$.002 = 1877.77 W$$

$$\boxed{W = 1.065 \mu m}$$