EECS 2077 Test #4, Spring 2014 Name:____

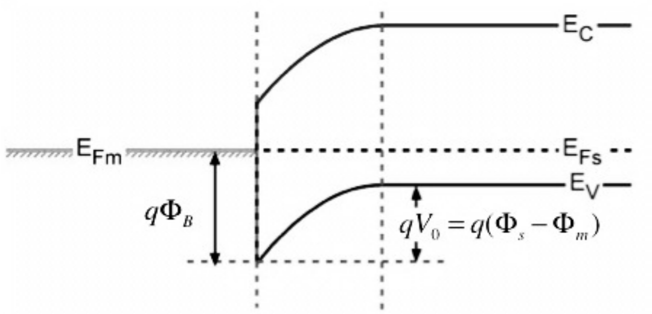
#1 ____/25 pts	**Allowed materials: 4 pages of 1-sided equation sheets, writing utensil, calculator.**		
#2 ____/22 pts	**Remember – we use cgs units! Centimeter/gram/second.**		
#3 ____/25 pts	kT = 0.026 eV (300K)	ε_0=8.854x10^{-14} F/cm	ε_r(Si)=11.8
#4 ____/28 pts	q= 1.6x10^{-19} C	n_i(Si)=1.5x10^{10} / cm^3	ε_r(SiO_2)=3.9

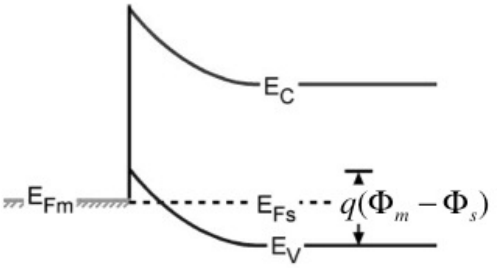
1.) 25 pts. Two metal/semiconductor junctions are given below. For both junctions:

a) [9 pts] draw the IV diagram for both positive and negative voltage applied to the junctions, **with respect to voltage applied to the metal** (assume semiconductor is grounded);

b) [8 pts] on each plot, for **positive voltage** label the **carrier type** that dominates the current flow on the semiconductor side of the junction;

c) [8 pts] on each plot, for **negative voltage** label the **carrier type** that dominates the current flow on the semiconductor side of the junction.

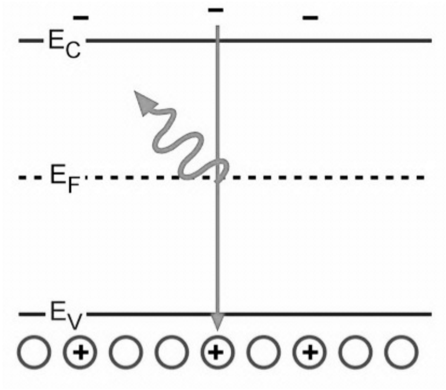




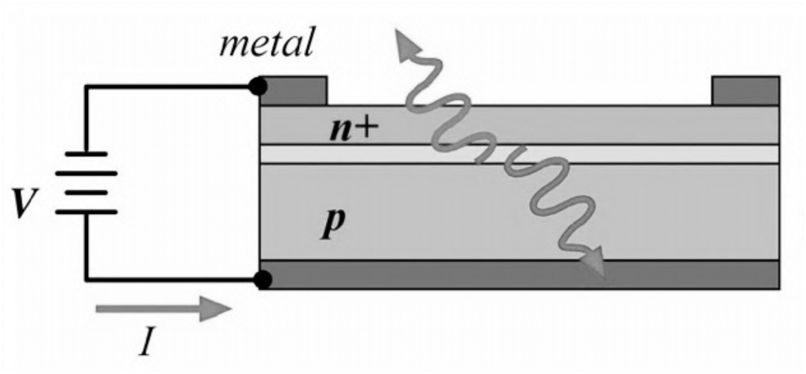
2.) 22 pts. Lasers!

(a) [16 pts, 4 pts per answer] See the light emitting devices below. For the band-diagram in (a), there are TWO things that we can see that shows us that this is not a LASER, what are they? For the device diagram in (b), the device requires TWO device structure modifications to become a laser, what are they?

(a)



(b)



(c) [6 pts] A laser with a refractive index of 2.7 for the semiconductor emits a laser light with a wavelength of 1.07 µm. Which of the following is a possible length (distance) between the mirrors of the laser?

___ 288.9 µm
___ 107 µm
___ 39.6 µm
___ all the above

3) [25 pts] Question related to an n-MOS transistor with the following parameters:

The gate electrode ‘metal’ is n+ poly Silicon.

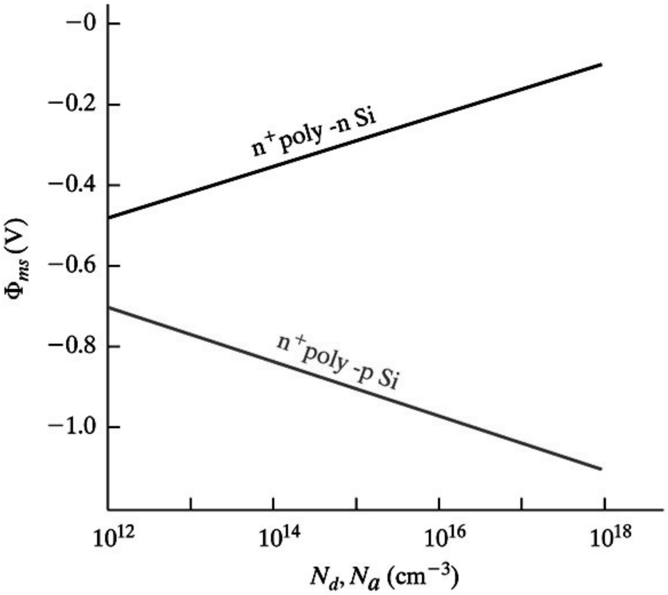
The substrate is doped with Boron to the level of $Na=10^{16}/cm^{3}$.

In the plot shown at right, the curves are labeled as ‘gate material – substrate material’.

The gate oxide is has a thickness of 5 nm and a dielectric constant of 4.

There is no interface charge (Qi).

$$V_T = \phi_{ms} - \frac{Q_i}{C_i} - \frac{Q_{D,\max}}{C_i} + 2\phi_f$$



a) provide the value for how much the Fermi level in the substrate has been shifted due to doping (deeper into the substrate, where the bands are flat) [5 pts]:

b) provide the value for the maximum capacitance that a 1 μm^2 area gate electrode will see during operation [5 pts]:

c) provide the value for the maximum depletion charge [5 pts]

d) provide the value for how much threshold voltage is influenced by the fact that the Fermi level of the gate electrode and the Fermi level of the substrate Si, have to shift to match up [5 pts]:

e) provide the threshold votlage for this device [5 pts]:

4) [28 pts, 4 pts each] Drift vs. diffusion!

(a) Exists at 300K for a diode in thermal equilibrium (with no voltage applied to it).

DRIFT DIFFUSION BOTH NEITHER

(b) Increases as you shine light on a photodiode.

DRIFT DIFFUSION BOTH NEITHER

(c) Is how carriers are injected from the emitter into the base of a BJT.

DRIFT DIFFUSION BOTH NEITHER

(d) For a metal/semiconductor diode made on top of n-type Si, is the possible types of current for holes.

DRIFT DIFFUSION BOTH NEITHER

(e) A JFET would have an current-to-current amplification factor of infinity if it were not for this.

DRIFT DIFFUSION BOTH NEITHER

(f) Requires particles that have electrical charge and electric field.

DRIFT DIFFUSION BOTH NEITHER

(g) Requires a concentration gradient.

DRIFT DIFFUSION BOTH NEITHER

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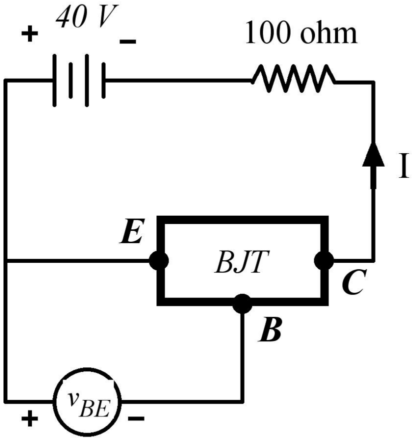
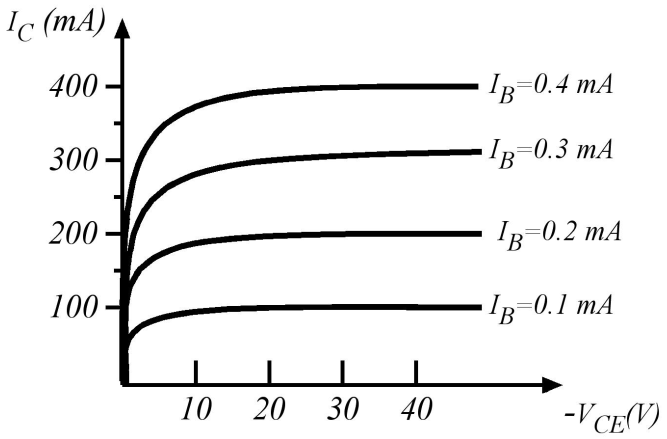
#5 ____/25 pts **Allowed materials: 4 pages of 1-sided equation sheets, writing utensil, calculator.**
#6 ____/25 pts **Remember – we use cgs units! Centimeter/gram/second.**
#7 ____/30 pts kT = 0.026 eV (300K) ε_0=8.854x10^{-14} F/cm ε_r(Si)=11.8
#8 ____/20 pts q= 1.6x10^{-19} C n_i(Si)=1.5x10^{10} / cm^3 ε_r(SiO_2)=3.9

5.) BJTs :)

a) [10 pts] Draw a band diagram of a NPN BJT in normal forward active mode. *Include on your drawing the key carriers required for operation, the Fermi level locations, show how electron current moves through the device with arrows, and properly label the arrows as 'drift' or 'diffusion'.*

b) [10 pts.] A PNP BJT is put in the following circuit, and has the following stand-alone Ic vs. Vce characteristic. Graphically determine both the *circuit* current (I) and V_{CE} for a base current (I_B) of 0.4 mA.



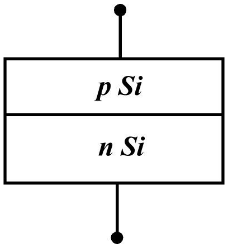


c) [5 pts.] For this equation predicting collector current for a BJT, explain the basic three components of the equation (i.e. what does each really mean in simple language?).

$$I_C \approx qA\frac{D_p}{L_p}\ \Delta p_E\ \mathrm{csch}\frac{W_b}{L_p}$$

6.) 25 pts. An **ideal** Si pn+ junction at 300K has the following parameters (you may or may not need them all).

p-side:	n-side:	General parameters
$Na=10^{15}/cm^3$	$Nd=10^{17}/cm^3$	$\varepsilon_{Si}\varepsilon_0=1x10^{-12}$ F/cm (11.8 x ε_0 F/cm)
		reverse sat. current $I_0 = 4.5x10^{-14}$ A
		contact potential $V_0 = 0.7$ V



a) [10 pts.] What are the ideal values for drift (I_{drift}) and diffusion (I_{diff}) currents across the junction at an applied forward bias of +0.5V?

b) [8 pts.] Calculate the width of the depletion region (W) for the case of zero applied voltage.

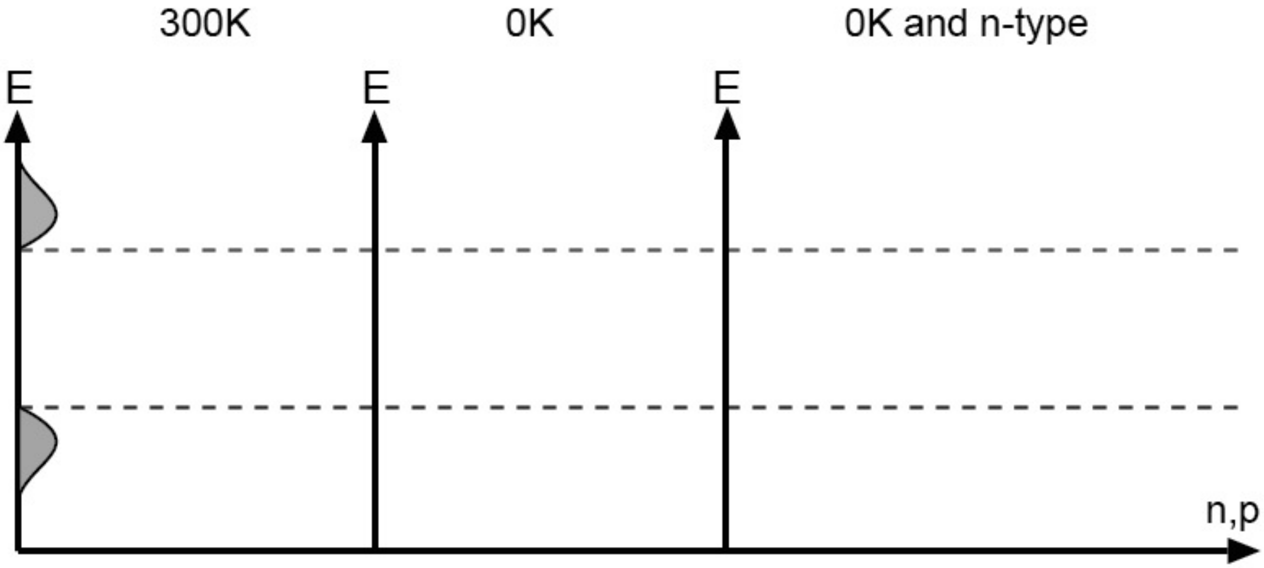
c) [7 pts] If you used these exact PN junction materials to make a JFET, draw the JFET and diagram how far apart the gate regions have to be (channel width) to have a conducting channel that is 1 µm wide with no voltage applied to the gates, source, or drain electrodes.

7) 30 pts. A mish-mash of a few more problems…

(a) [5 pts] qualitatively plot the mathematical function for density of states and for Fermi distribution for ‘300K’

(b) [5 pts] qualitatively plot the mathematical function for density of states and for Fermi distribution for ‘0K’

(c) [10 pts] redraw the electron and hole concentrations, density of states, Fermi distribution, and Fermi level, for ‘0K & n-type’ *careful, think about this last one before you do it! Trust your understanding!*



(d) [10 pts] For the following drain current formula for some new unknown device, provide a formula that will predict the transconductance:

$$I_D = 5V_G^2 e^{2V_G} + 32V_D \text{ (mA)}$$

8.) [20 pts] Cataclysmic lab accident! And a bunch of cubes of semiconductors, metals, and oxides have been fused together. And you have a deadline and need some semiconductor devices to test some circuits. What terminals would you use?

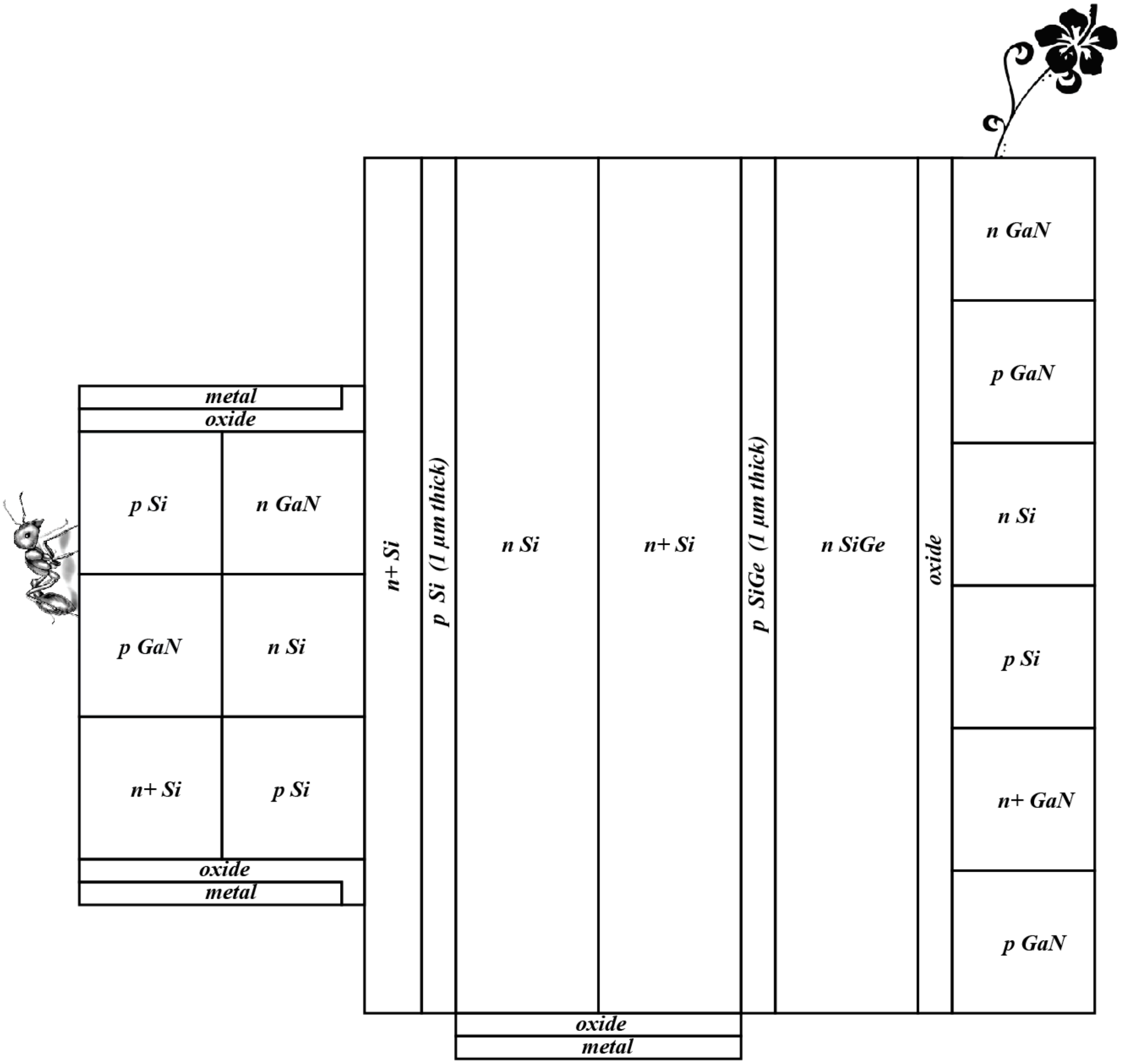
Add to the diagram the terminals (wire contacts) you would use for each answer and label the (a), (b), etc. so I know which question you are answering.

a) [5 points] Highest breakdown voltage diode.

b) [5 points] Amplifier with the least amount of input current needed to modulate the output current.

c) [5 points] Amplifier with the highest emitter injection efficiency.

d) [5 points] Highest responsivity photodiode for ultraviolet light.



EXTRA SPACE