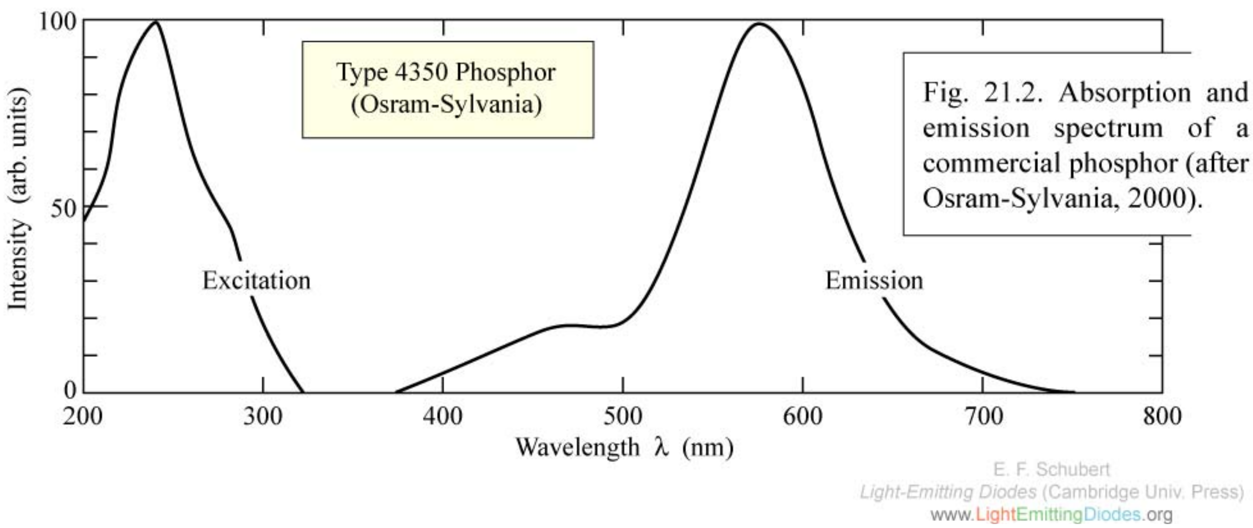
EECS 2077 Test #4, Winter 2015 Name:______________________________

#1 ____/25 pts	**Allowed materials: 4 pages of 1-sided equation sheets, writing utensil, calculator.**		
#2 ____/25 pts	**Remember – we use cgs units! Centimeter/gram/second.**		
#3 ____/15 pts	kT = 0.026 eV (300K)	ε_0=8.854x10^{-14} F/cm	ε_r(Si)=11.8
#4 ____/35 pts	q= 1.6x10^{-19} C	n_i(Si)=1.5x10^{10} / cm^3	ε_r(SiO_2)=3.9

1) 25 pts. Some opto problems.

a) 10 pts. Below is a simple LED that creates yellow light by use of a phosphor. Question… what percent of the emitted diode optical power is automatically lost in order to create the yellow light? Do a rough calculation based on peak wavelengths and energy….



b) 5 pts. Is the above device more or less efficient in power conversion than a standard commercial white LED (be sure to BRIEFLY explain why in ONE sentence max).

c) 10 pts. Modify the equation below by crossing out ALL terms we can eliminate for using a p+n junction as a photodetector (assume the p-type doping is 1000X higher than the n-type doping).

$$qA\left(\frac{L_p}{\tau_p}p_n+\frac{L_n}{\tau_n}n_p\right)\left(e^{qV/kT}-1\right)-qAg_{op}\left(L_p+L_n+W\right)$$

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2) [25 pts.] An <u>ideal</u> p+n junction at 300K, made out of an unknown material (is not Si) has the following parameters (you might not need them all).

p-side:	n-side:	General parameters
$Na=10^{17}/cm^3$	$Nd=10^{15}/cm^3$	$\varepsilon=6.8$
$Dn=50\ cm^{2/}sec$	$Dp=100\ cm^{2/}sec$	$n_i=1.5x10^{10}\ /\ cm^3$
$Ln=20x10^{-3}$ cm	$Lp=50x10^{-2}$ cm	

a) [10 pts] What are the DRIFT and DIFFUSION current densities (A/cm^2) across the junction at an applied <u>reverse bias of -5V</u>?

Calculations:

Answer for DRIFT: __________

Answer for DIFFUSION: _________

b) [10 pts] What are the DRIFT AND DIFFUSION current densities (A/cm^2) across the junction at a <u>forward bias of 0.6? V</u>?

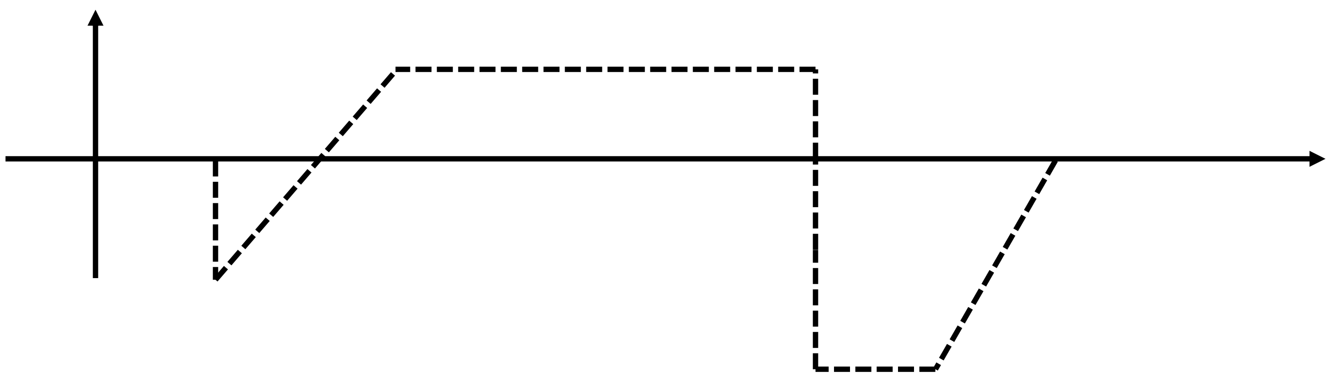
Calculations:

Answer for DRIFT: __________

Answer for DIFFUSION: _________

c) [5 pts] Under reverse bias, what type of carrier dominates? Circle one: electrons / holes / neither

3) [15 pts] Draw the band-diagram (just conduction and valance bands) for the following E-field profile. Draw the band-diagram directly below the E-field profile so I can match them up. (The dotted line is the E-field, Y-axis is E-field with positive E-field above the X-axis, X-axis is positive distance). Use the provided space below so I can clearly see how the band diagram changes…



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4) [35 pts] Question related to a NMOS device with the following parameters:

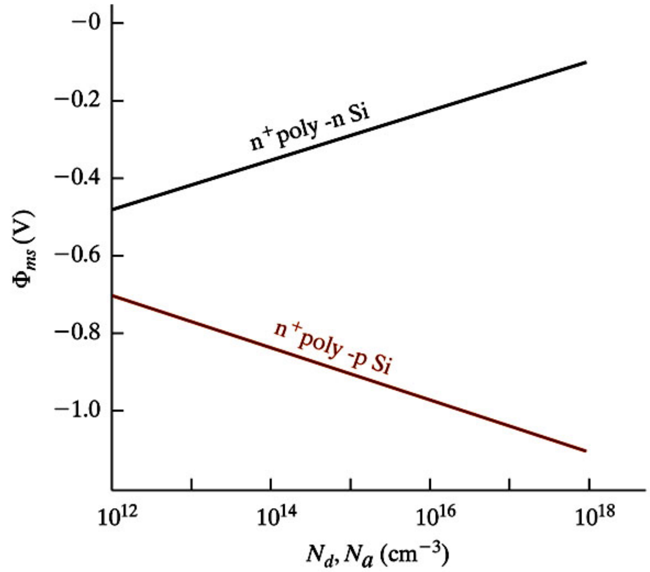
The gate electrode 'metal' is n+ poly Silicon.

The substrate is doped with Boron to the level of $N_a=10^{17}/cm^3$.

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

The gate oxide is has a thickness of 15 nm and a dielectric constant of 4.

There is an interface charge (Qi) of -20 nC/cm^2.



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

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

b) calculate the capacitance per unit area of the gate oxide [5 pts]:

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

d) for each of your answers above for (a) and (c), tell me if they increase OR decrease the required threshold voltage (in terms of magnitude):

a – INCREASE / DECREASE [5 pts]

c – INCREASE / DECREASE [5 pts]

e) the interface charge. Does it increase or decrease your threshold voltage?

INCREASE / DECREASE [5 pts]

f) the difference between the metal (gate electrode) work function and the semiconductor workfunction, does it increase or decrease your threshold voltage?

INCREASE / DECREASE [5 pts]

EXTRA SPACE

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#5 ____/25 pts	**Allowed materials: 4 pages of 1-sided equation sheets, writing utensil, calculator.**		
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#7 ____/15 pts	kT = 0.026 eV (300K)	ε_0=8.854x10^{-14} F/cm	ε_r(Si)=11.8
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Mish mash of problems to start…

5a) [10 pts] A semiconductor with ni=10^9/cc is doped n-type to Nd=10^{15}/cc, and we optically generate 5x10^{17} electron-hole pairs. If the electron and hole mobility is the same, for a given voltage applied to the semiconductor how much will the drift current increase due to the optical generation?

5b) [5 pts ea.] Drift vs. diffusion…

(a) Increases as you increase doping for a diode with forward bias on it.

DRIFT DIFFUSION BOTH NEITHER

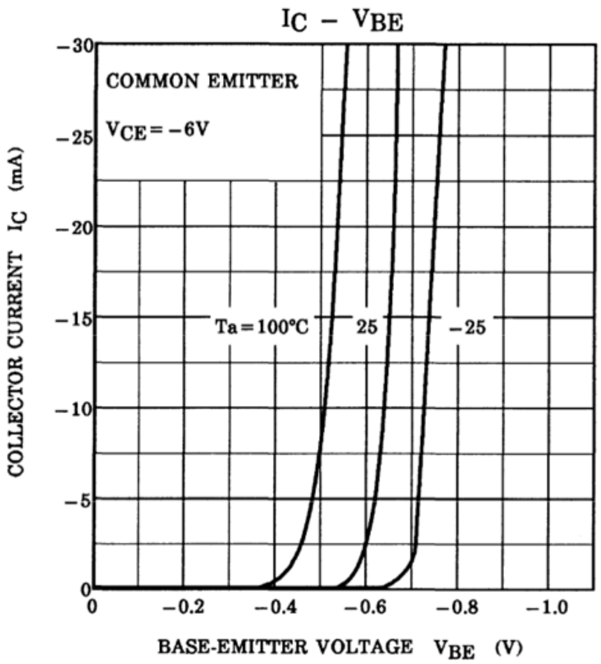
(b) Is how carriers are transported across the base-collector depletion region of a BJT.

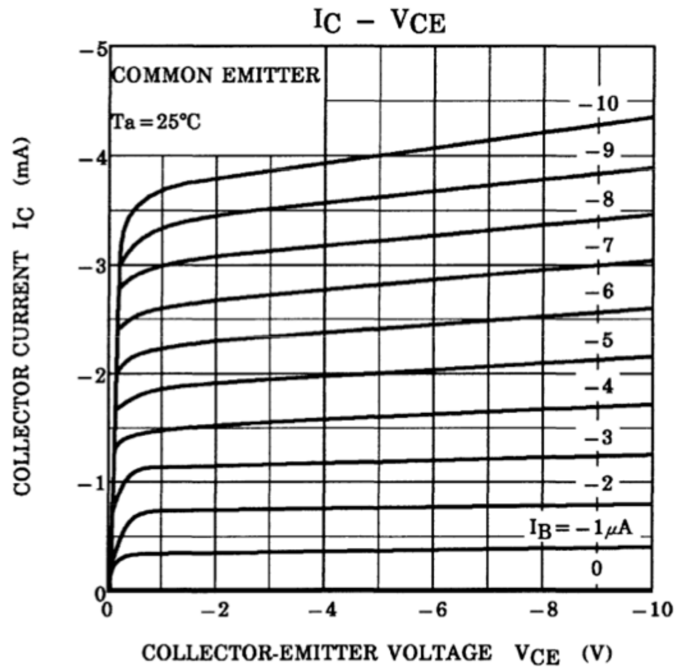
DRIFT DIFFUSION BOTH NEITHER

(c) Separates photogenerated carriers inside a solar cell so that they can be collected.

DRIFT DIFFUSION BOTH NEITHER

6) BJTs… [25 pts]





(a) [9 pts] the above I-V characteristics are for a PNP BJT. For the case of V_{CE} = -8V and I_b=6 μA, if I add one more electron to the base, how many more holes will be collected?

(b) [9 pts] Roughly, how much power is dropped across the base-collector depletion region for the case of V_{CE} = -8V and I_b=6 μA?

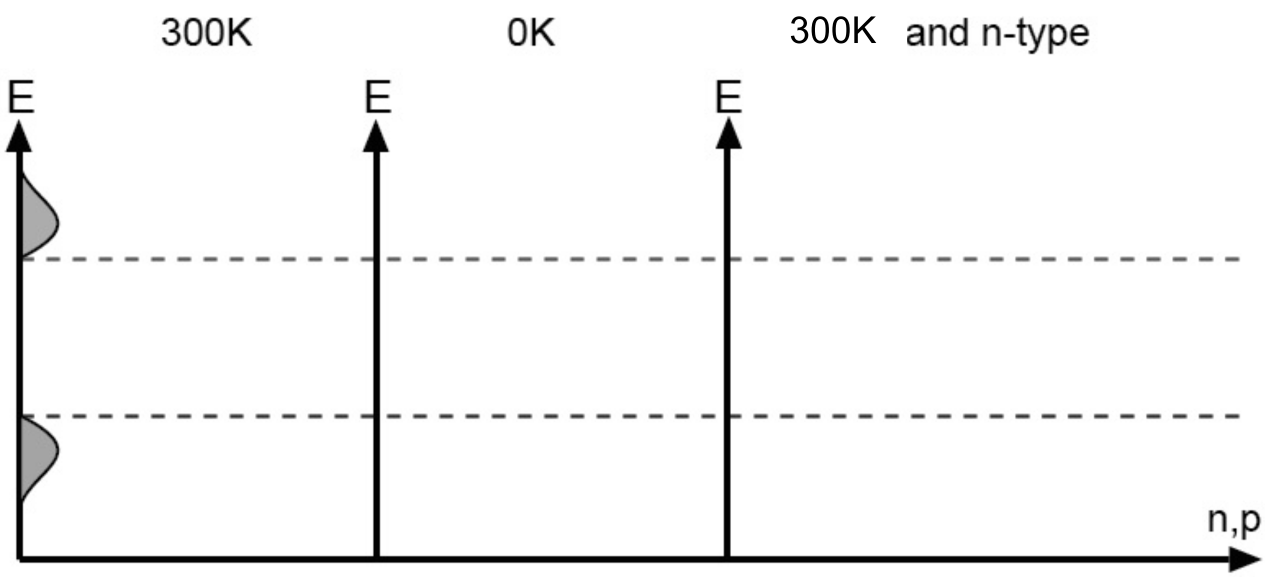
(c) [7 pts.] Draw the load-line solution on the correct choice of the two plots above for the case if the BJT had 2 kohm output resistance.

7) 26 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) [7 pts] redraw the electron and hole concentrations, density of states, Fermi distribution, and Fermi level, for '300K and n-type'.



(d) [9 pts] For the following drain current formula for some new unknown device, provide a formula that will predict the transconductance:

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

8.) [24 pts, 8 pts ea.] Another lab accident! Shouldn't we modify our safety policies perhaps?

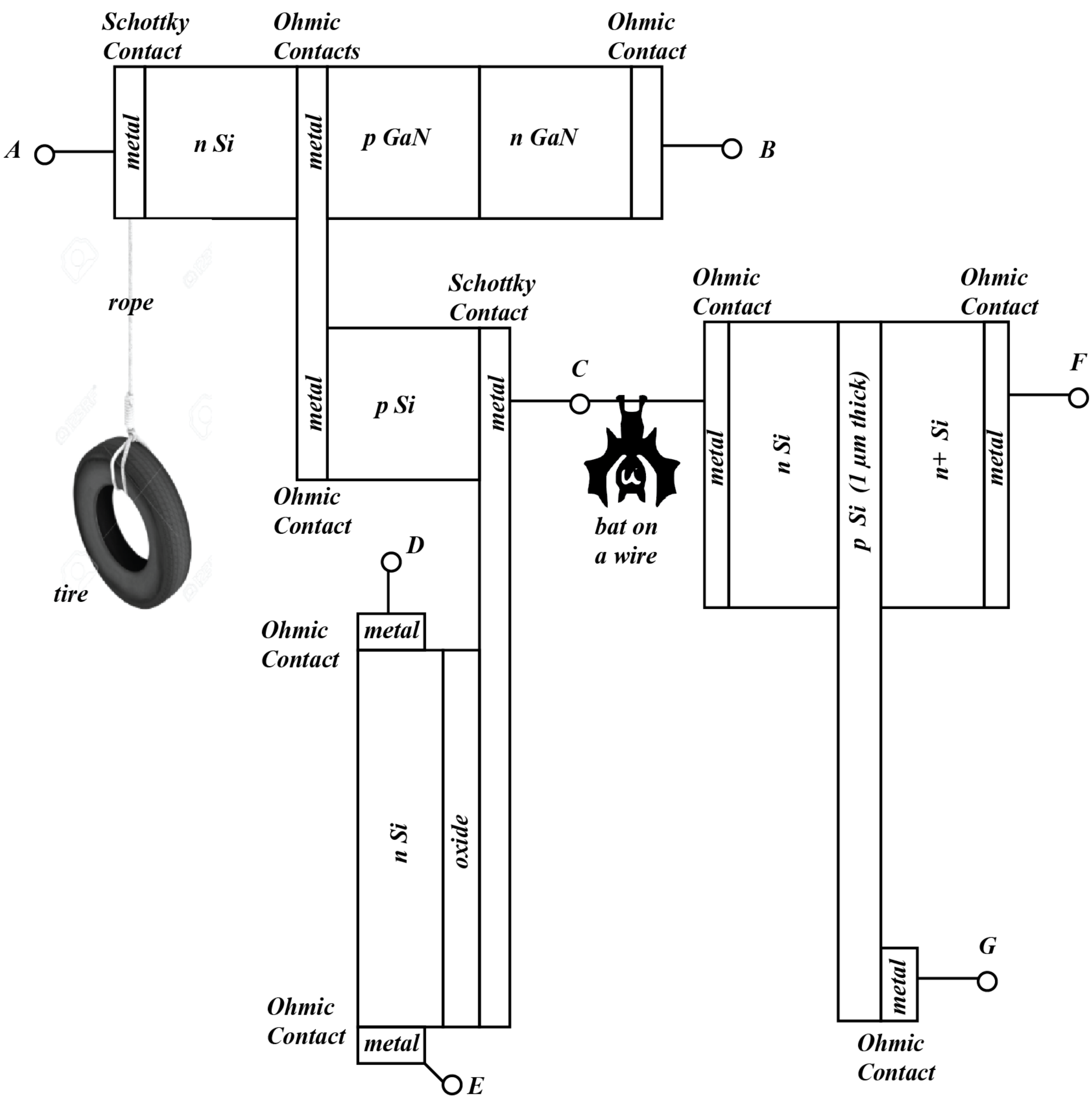
A bunch of cubes of semiconductors, metals, and oxides have been fused together. The lab is destroyed, you are bored with nothing to do now, so you set out to play with what is left…

a) Which terminals and what polarities (+ or -) do you need to get light emission in the UV? ____________

b) Which terminals to turn the GaN diode into a photodetector? ____________

c) What polarity on terminal C to get min resistance between D and E? *Assume D&E are close to 0V.* ____

d) What terminals and what polarities (+ or -) would you need to bias to get the best possible photodetector (highest A/W) for red light. List ONLY the terminals that would need voltage (don't add extras). __________



EXTRA SPACE