EE 121 **FINAL REVIEW**
Watkins

General Comments:

- Closed Book, Closed Notes, and Comprehensive.
- *Equation sheets and Periodic Chart will be included.*
- Mainly numerical, but may include definitions, sketches, qualitative answers, etc.
- Formulas, sketched, and steps to answer must be shown for full credit.
- Appropriate units must be given in all answers.
- Unit conversions and words for acronyms will be provided upon request.
- Partial credit will be given.
- No derivations will be included

The following items are allowed during this examination:

- Calculator

The following items are NOT allowed during this examination:

- Notes, books, and cell phones

Review Items (in order of priority):

- Lecture Notes, Quizzes, Homework Solutions, and Handouts.

Examination Content: (10 Problems of which 8 Problems will be Graded)

- Semiconductor Crystal and Junction Physics (2 problems)
- Diode Circuits (1 problem)
- Bipolar Junction Transistors (2 Problems)
- Field Effect Transistors (2 Problems)
- OpAmp Circuits (2 Problems)
- Photodiodes (1 Problem)

Examination Material:

- Electrical Concepts – current, current density, voltage, electric field, Ohm's law, insulators, conductors, resistance, resistivity, conductivity, temperature dependence, and associated units.
- Crystals and Carriers – electronic configuration of atoms, valence electrons, use of the periodic table, bonding types, nearest neighbors, band structure for insulators and semiconductors, valence band, conduction band, energy gap, steady-state and equilibrium conditions, elemental and compound semiconductors (Col IV and Col. II-V), intrinsic and extrinsic semiconductors, carrier concentration vs. 1/T, identification of dopants, donors, acceptors, electrons, holes, p-type, and n-type.
- Charge Carriers - calculations of n_0 and p_0 for complete impurity ionization, Fermi levels, compensation, drift current in an electric field, resistivity, resistance, conductivity, mobility, variation of mobility with impurity concentration, diffusion current in a concentration gradient, diffusion coefficient, and Einstein relation.

- Junctions and Diodes - contact potential calculations, energy band diagrams, charge density diagrams, calculations for an abrupt junction (V_o, W, x_{no}, x_{po}, Q_+, and Q_-) in equilibrium and under bias, low-level injection diode equation, geometry and circuit symbol with voltage and current conventions, graphical load line-diode characteristic solutions of operating point, forward-bias qualitative effects (on diode equation) of high-carrier injection and ohmic losses, reverse-bias effect of breakdown, p^+n and n^+p junctions, and diode circuits.
- Bipolar Junction Transistor – symbol, structure, terminal names, and IV characteristics for both npn and pnp types; energy band diagrams and carrier specifics for equilibrium and typical bias; current relationships including emitter injection efficiency, base transport factor, current transfer ratio, and gain; design optimization for high gain; regions of the IV characteristic; common-base circuit; common-emitter circuit; common-emitter circuit with R_e; Darlington amplifier circuit with 2 transistors; constant current circuit; single biasing source configuration; and emitter follower circuit.
- Junction Field Effect Transistor – symbol, structure, terminal names, and IV characteristics for both n-channel and p-channel JFET types; energy band diagrams and carrier specifics for equilibrium and typical bias; pinch-off voltage and saturation current; design optimization; regions of the IV characteristic; current equations for unsaturated and saturated regions; common-source circuit; source-follower circuit; and self-biasing circuit.
- Metal Oxide Semiconductor Field Effect Transistor – symbol, structure, terminal names, and IV characteristics for both n-channel and p-channel MOSFET types (both depletion-mode and enhancement mode); typical bias conditions; pinch-off or turn-on voltage and saturation current; current equations for unsaturated and saturated regions; and inverter circuit with enhancement-mode and depletion mode MOSFETs.
- Operational Amplifiers – OpAmp model with finite resistances, ideal OpAmp parameters and model, buffer OpAmp circuit, non-inverting OpAmp circuit, inverting OpAmp circuit, multiple input circuits (adders and subtractors), voltage-to-current or current-to-voltage circuits, integrating and differentiating circuits, and multiple stage analysis.
- Optoelectronics – wavelength, frequency, photon energy, phase velocity, refractive index, absorption coefficient, semiconductor absorption, semiconductor emission (injection luminescence), photodiode equation with I_{light}, photodiode efficiency, photoconductive mode, pin photodiode structure, avalanche photodiode structure (APD), photodiode biasing circuit, LED operation, three requirements for a laser, and laser diode operation.
- Miscellaneous - Semiconductor fabrication (four requirements for a semiconductor device) units of all quantities and n_i for Si, Ge, and GaAs at RT.

Name ________________

Instructor ________________

Section/College ________________

Score ____________/200

EE 121 FINAL/ADVANCEMENT EXAM III

SAMPLE SEMESTER 20XX

CLOSED BOOK

TWO (2) HOUR LIMIT

CALCULATORS ARE ALLOWED

CELL PHONES MAY NOT BE USED

There are 10 problems: please look over the examination to make sure that you have 10 different problems. **Do any eight (8) problems!** Draw a large X through the two problems that you do not want to be graded. If you do not indicate which problems you want to leave out, the first 8 problems will be graded.

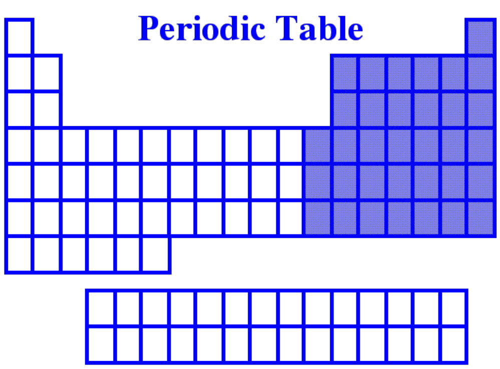
Do all work for each problem only on the page supplied for that problem (you may use both sides). **DO NOT**, for instance, continue Problem #3 on the back of Problem #2. Extra blank paper will be supplied if needed. If extra paper is used, show the additional work for each problem on a separate sheet and staple the extra sheet(s) to the appropriate problems.

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10

EE 121 FINAL EXAM REFERENCE

READ THE ENTIRE EXAM BEFORE YOU BEGIN
SHOW FORMULAS USED AND STEPS TO ANSWER
ANSWERS MUST HAVE CORRECT UNITS
PUT A BOX AROUND THE ANSWER

Boltzmann's constant:	$k = 1.381 \times 10^{-23}$ J/K = 8.618×10^{-5} eV/K		
Planck's constant	$h = 4.136 \times 10^{-15}$ eV-sec = 6.626×10^{-34} J-sec		
Electronic charge:	$q = 1.602 \times 10^{-19}$ C		
kT at 300 K	kT = 0.0259 eV	eV-J conversion	1 eV = 1.602×10^{-19} J
Free-space permittivity	$\varepsilon_o = 8.854 \times 10^{-14}$ F/cm	Speed of Light	$c = 2.998 \times 10^{10}$ cm/s
Relative permittivity	Si: 11.9	Ge: 16.0	GaAs: 13.1
Bandgap energies	Si: 1.12 eV	Ge: 0.67 eV	GaAs: 1.42 eV



IIB	IIIB	IVB	VB	VIB	VIIB	VIII
						He
	B	C	N	O	F	Ne
	Al	Si	P	S	Cl	Ar
Zn	Ga	Ge	As	Se	Br	Kr
Cd	In	Sn	Sb	Te	I	Xe
Hg	Tl	Pb	Bi	Po	At	Rn

1 Consider an abrupt pn junction of crystalline silicon (Si). Side #1 has ionized phosphorous (P) dopants only at $N_1 = 10^{16}$ cm^{-3} and side #2 has ionized aluminum (Al) dopants only at $N_2 = 10^{16}$ cm^{-3}.

1(a) Identify the junction sides as p-type or n-type. Circle the best choice. (5 pts.)

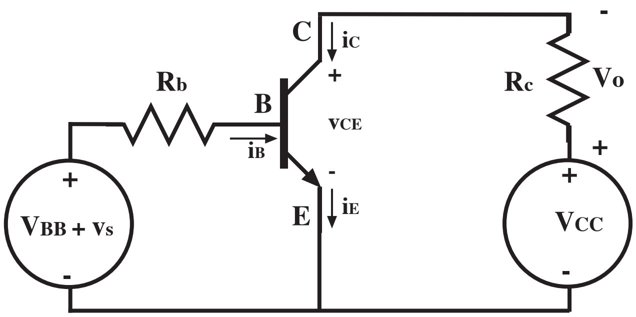
Side #1 p-type & Side #2 n-type **Side #2 p-type & Side #1 n-type**
Insufficient information

1(b) Calculate the contact potential V_o (for equilibrium) (10 pts.)

1(c) Consider the low-level-injection diode equation. Calculate the reverse-bias voltage for which the current magnitude equals 90 percent of the reverse saturation current. The temperature is 300 K. (5 pts.)

#1

2 For the BJT circuit given let V_{BB} = 5.0 V, v_S =0 V, R_b = 5.0 kΩ, V_{CC} =15.0 V, and R_c=100 Ω. Assume the base-emitter turn-on voltage is 0.7 V and β = 100.

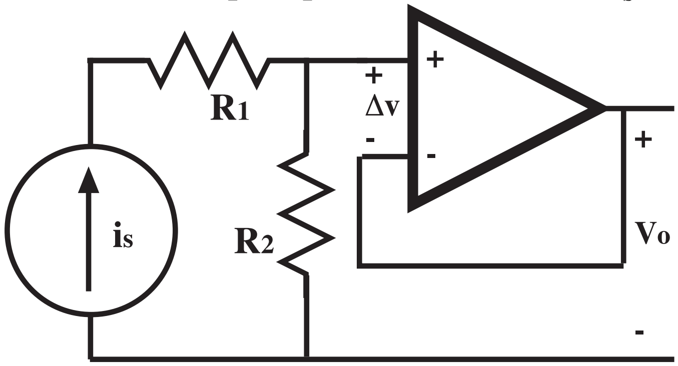


2(a) Calculate the base current i_B. (5 pts.)

2(b) Calculate the operating point, i.e. the voltage v_{CE} and the collector current i_C. (15 pts.)

#2

3 Consider the OpAmp circuit below with $i_S = 1.0 \sin(10t)$ mA. Let $R_1 = R_2 = 100\ \Omega$.

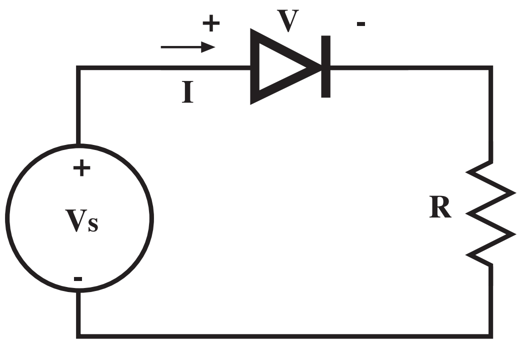


3(a) Draw the equivalent circuit in which the OpAmp is replaced with the appropriate circuit elements. Assume **ideal** input and output resistances (R_{out} and R_{in}) and a finite gain A. (5 pts.)

3(b) Calculate v_o as a function of t (time). Solve with a finite A and then let A go to infinity. (15 pts.)

#3

4 The Si p-i-n photodiode shown is reverse-biased for source voltage $V_S = -100$ V. The reverse saturation current is 0.050 mA and the quantum efficiency is $\eta = 0.70$ for $\lambda = 900$ nm. Assume the diode voltage $|V| >> kT/q$. The diode voltage and diode current are $V = -50$ V and $I = -0.50$ mA.



4(a) Calculate the optical power absorbed. (10 pts.)

4(b) Calculate the required resistance. (10 pts.)

#4