NAME: ____________________________

Guidelines:
1. Open book, open notes, open mind. No communication with others.
2. Time limit: 1 hour 15 minutes (in-class).
3. Mark directly on the handout.

The midterm counts for 25% towards the final grade.
Problem 1 (20 Points):

Sketch the cross-section of possible fabricated structures for the following devices in a standard CMOS process. Denote n and p doped regions (including substrate, well and base regions, if any). You may assume p-base is available in an n-well process, and n-base in a p-well process. Denote all terminals, including bulk/substrate terminals to GND or Vdd where needed.

1a. An nMOS folded cascode mirror in a p-well process (terminals IN, OUT, Vbn and Vcn);

1b. An nMOS transistor in an n-well process (terminals S, G, D, B; all terminals disconnected from the substrate);
1c. An *nnp* lateral bipolar transistor in a *p*-well process (terminals E, B, C, and G);

1d. A high-sensitivity photodiode in a *p*-well process (terminals OUT and Vdd, denote photosensitive region).
Problem 2 (40 Points):

Design a 3-bit, binary-code to Gray-code converter. Inputs are the three binary bits B2 (MSB), B1 and B0 (LSB); outputs are the three Gray bits G2, G1 and G0. Minimize the number of transistors used. Show the entire transistor-level circuit diagram. You may save ink by defining and instantiating subcircuit “cells” where this is helpful.
Problem 3 (40 Points):

Consider the current-mode circuit shown below.

1. (25 points) Find the output current \( I_{out} \) as a function of input current \( I_{in} \) and reference currents \( I_a \) and \( I_b \), assuming the transistors are identically sized and operate in the subthreshold region. You may ignore the Early effect (\( \lambda = 0 \)), and assume the output voltage \( V_{out} \) is sufficiently large.

2. (15 points) What happens to this relationship between input and output current if the nMOS transistors are replaced with npn BJTs? Quantify your answer. The BJTs are ideal with infinite current gain (\( \beta F \)).

3. BONUS: (15 extra points) What happens to the relationship between input and output current in the BJT version if the current source \( I_a \) is replaced with a capacitor \( C \)? Be specific and express the large-signal dynamics of \( I_{out} \) in response to \( I_{in} \).