

### DEVICES – Ph.D. Qualifying Exam Fall 2007

Values of constants:

$$q \text{ (charge on an electron)} = 1.6 \times 10^{-19} \text{ C}$$

$$\epsilon_0 \text{ (permittivity of free space)} = 8.85 \times 10^{-14} \text{ F/cm}$$

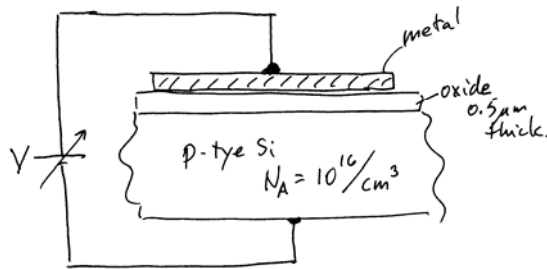
$$kT/q \text{ (at room temperature)} = 0.026 \text{ V}$$

$$n_i \text{ (concentration of intrinsic carriers in Si at room temperature)} = 1.08 \times 10^{10} / \text{cm}^3$$

(4% ) 1. Suppose you have a metal/ oxide/ p-type-silicon sandwich which forms a capacitor as shown.

a) Sketch qualitatively the AC capacitance ( $dQ/dV$ ) as the voltage is scanned from -10V to +10V. (This is the so called CV curve.)

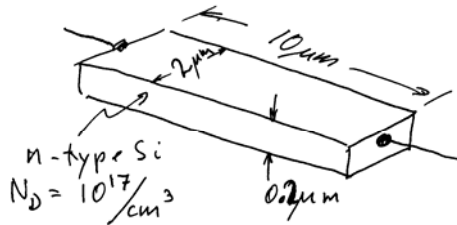
b) Identify the key points on the voltage axis and explain what is happening in the silicon in various voltage ranges.



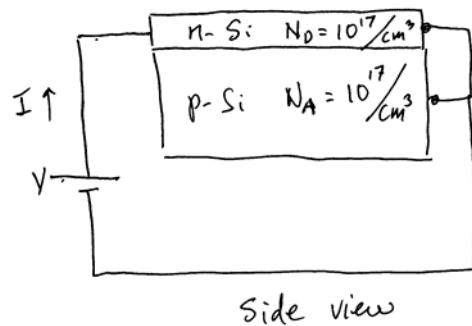
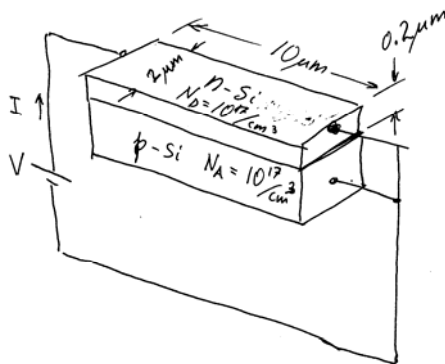
(4%) 2. a) Why is the collector of a bipolar junction transistor lightly doped? Give two reasons why this leads to more desirable performance.

b) Why are modern MOSFET's made with thinner and thinner gate oxides?

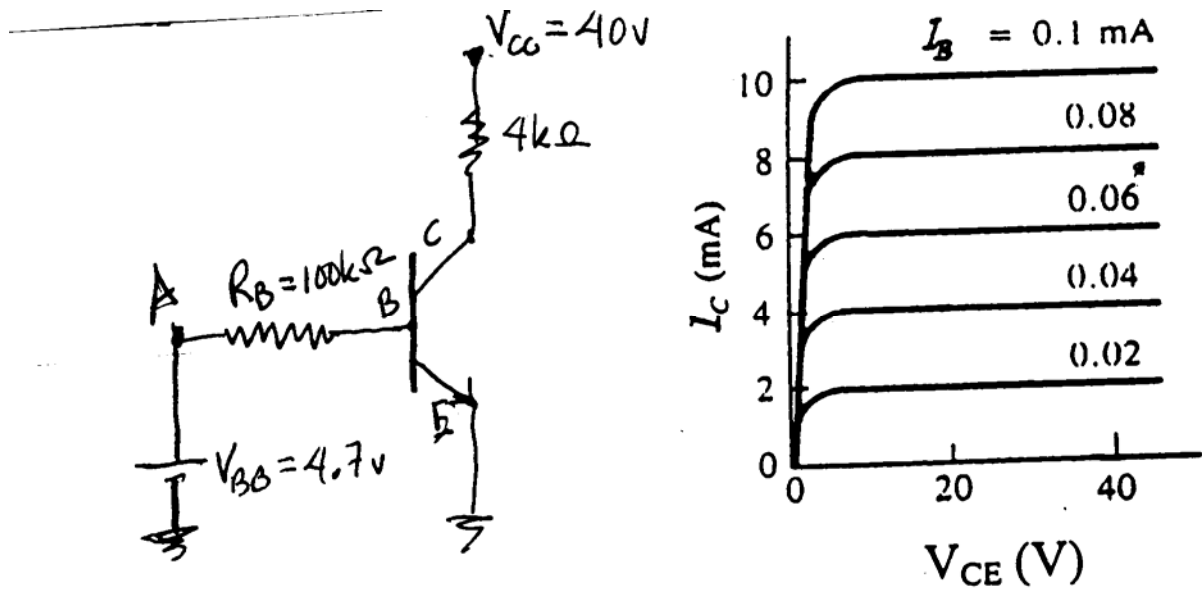
- (6%) 3. a) Suppose you have an n-type silicon slab doped with  $10^{17}$  donors/cm<sup>3</sup> as shown. The mobility of the silicon is  $1200\text{cm}^2/\text{V}\cdot\text{sec}$ . There are two contacts on the two ends. What is the end-to-end resistance between the contacts?



- b) Suppose you have the same n-layer mounted on a p-type substrate doped with  $10^{17}$  acceptors/cm<sup>3</sup>. Assume no current flows across the p-n junction. Would you expect to measure the same resistance as in part a) if you apply a low voltage, say  $V = 1\text{mV}$  as shown? Why or why not?



- c) Suppose you apply a higher voltage, say  $V = 2\text{V}$ , would you measure the same resistance as in part a) or part b)? Explain.



(6%) 4. Suppose you have a bipolar transistor with I-V characteristics shown connected in the circuit on the left.

- If the base-to-emitter voltage,  $V_{BE}$ , is  $0.7\text{V}$ , what is the base current,  $I_B$ ?
- Suppose you adjust the values of  $V_{BB}$  and/or the base resistor  $R_B$  so that the base current is  $0.06\text{mA}$ .
  - Given the I-V characteristic what is the collector current,  $I_C$ ?
  - What is the emitter current?
  - What is the collector voltage,  $V_{CE}$ ?