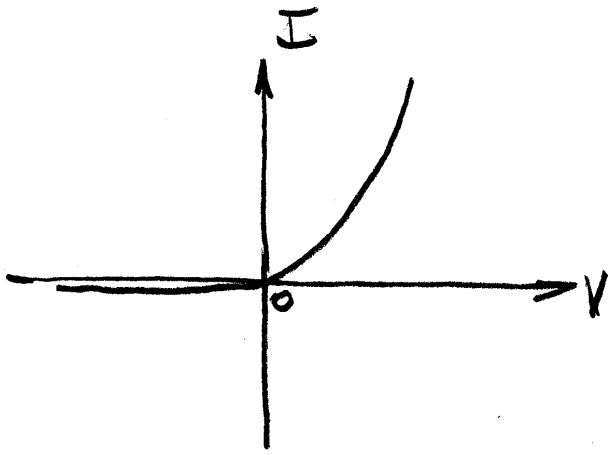
DEVICES - Ph.D. Qualifying Exam Fall 2008

(4%) 1. a) What happens to the electrical properties of a semiconductor such as silicon when its temperature is raised well above room temperature? Explain.

b) The figure below shows the room temperature I-V characteristic of a silicon diode. Show how this characteristic would be altered as the temperature is raised. Show for a moderate increase in temperature, and a large increase in temperature. (label curves and state your reasoning)

c) Show (and label) on the figure how the I-V characteristic of the diode would be changed if its temperature is lowered to near absolute zero.



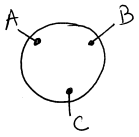
(5%) 2. a). Consider a conventional capacitor consisting of two facing metal plates and consider a PN junction which when reverse biased also acts as a capacitor.

i) How does the capacitance vary with applied voltage in the two cases?

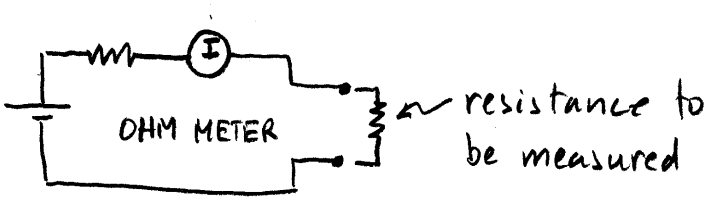
ii) Explain the physical origin of the difference in behavior. (Sketch if you wish)

b) You have two PN junctions. One is more highly doped on both the N and the P side than the other. At the same reverse bias voltage would you expect the heavier doped junction to have higher or lower capacitance than the junction consisting of two more lighly doped materials? Explain.

(5%) 3. Suppose you have a three terminal device and you know that it is either a bipolar transistor or a depletion mode MOSFET (i.e. a voltage has to be applied to turn off the channel).



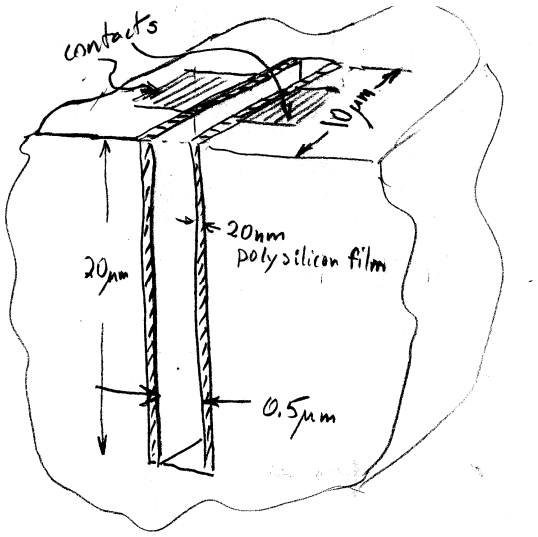
An ohm meter could be used to determined which it is. (An ohm meter is a two terminal instrument. See sketch. It measures the resistance connected between the two terminals by applying a small DC voltage and measuring the current.)



a) Without describing a procedure state what is the essential property of the three terminal device you would need to determine to say whether it is a bipolar junction transistor or a MOSFET.

b) Describe the procedure you would use to determine whether it is a bipolar transistor or a MOSFET. Hint: be careful, consider all posibilities.

(6%) 4. Suppose you have a trench capacitor in silicon dioxide consisting of two, 20nm thick, films of polysilicon on the sides of the trench which is 20 μm deep, 10 μm long and 0.5 μm wide, as shown The resistivity of polysilicon is 1.0 ohm-cm. The electronic circuit is on the top surface and connects to the top edges of the polysilicon.



a) Explain why the properties of this capacitor as a circuit element would vary as a function of frequency.
b) Estimate roughly at what frequency changes would occur. Permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-14}$ F/cm (8.85×10^{-12} F/m)