

EECS 40, Fall 2007
Prof. Chang-Hasnain

Homework #10

Due at 5 pm in 240 Cory on Monday, 12/10/07

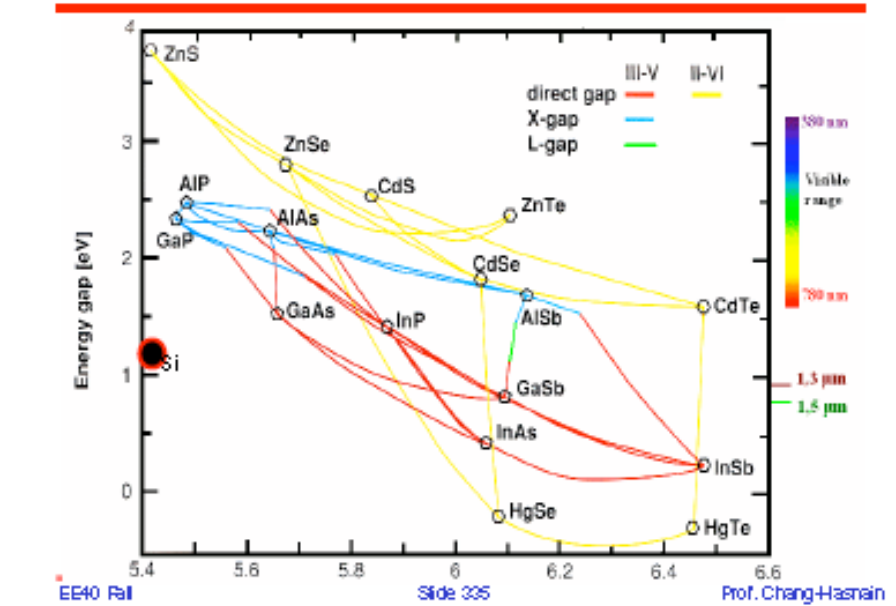
Total Points: 100

- Put (1) your name and (2) discussion section number on your homework.
- You need to put down all the derivation steps to obtain full credits of the problems. Numerical answers alone will at best receive low percentage partial credits.
- No late submission will be accepted except those with prior approval from Prof. Chang-Hasnain.

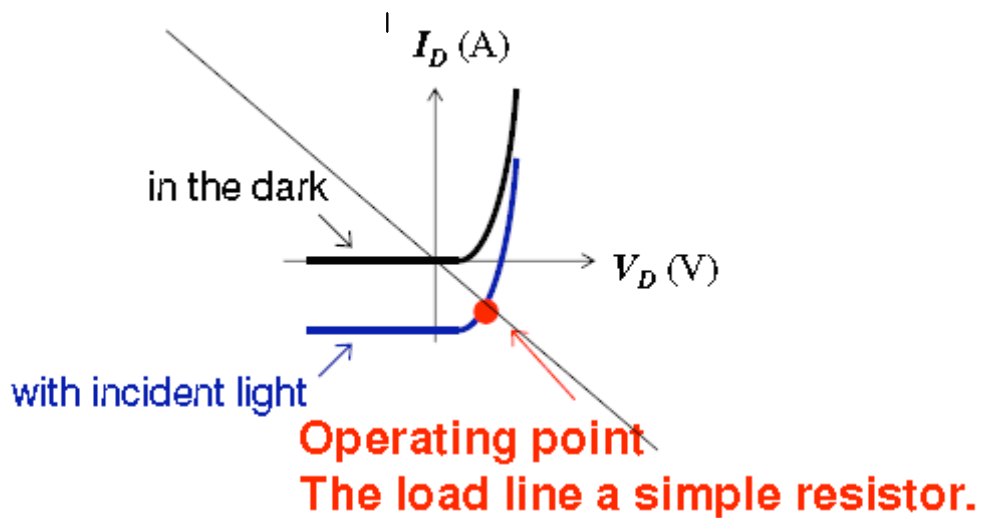
1. Solar cells and photodetectors (35 points)

1. What happens to the resistance of silicon when very intense radiation is applied to it? Why?
2. For a PN-junction under reverse bias (no radiation), what is the source of current?
3. What happens to an electron-hole pair in the intrinsic region of a photodiode, and why? (Assume no external voltage is applied, and then comment on the role external voltage would play).
4. What happens when red light is shined on Aluminum Arsenic? What about violet light? (see first figure below)
5. Suppose you know the amount of incident light, so that $I_D = f(V_D)$ (see second figure below). Write down the equation you would solve to find the operating point that maximizes power. Then write the resistor you would choose in terms of v_{opt} and $f(v_{opt})$ in order to achieve this operating point.
6. Suppose you have a number of curves, each corresponding to a different amount of incident light, and you are trying to maximize the amount of power generated. What would it mean if the curves ever intersected? What does this tell us about our ability to determine the amount of incident light (assuming we knew the curve for every value of incident light)?

Bandgap Versus Lattice Constant



Recall the following slide from class:



2. Analysis of an Amplifier (65 pts)

Amplifiers are essential building blocks in analog circuits and can be found in almost all electronic devices. Amplification requires the usage of nonlinear devices such as bipolar junction transistors (BJT) or metal oxide semiconductor field effect transistors (MOSFET). In this homework, you will fully analyze an amplifier based on a MOSFET. Before starting with this homework, you may want to read chapter 12 of the textbook.

- **Geometry of a MOSFET (10 pts)**
 - a. Sketch the model of an n-channel MOSFET. Clearly identify which regions are n and p doped. Also, mark the terminals. (5 pts)
 - b. Explain the principal operation of the MOSFET. Is the charge through the channel transported by holes or electrons? (5 pts)

- **II Large Signal Model of MOSFET (25 pts)**
 - c. In which modes can a MOSFET be operated. In which mode is the MOSFET a good amplifier? (5 pts)

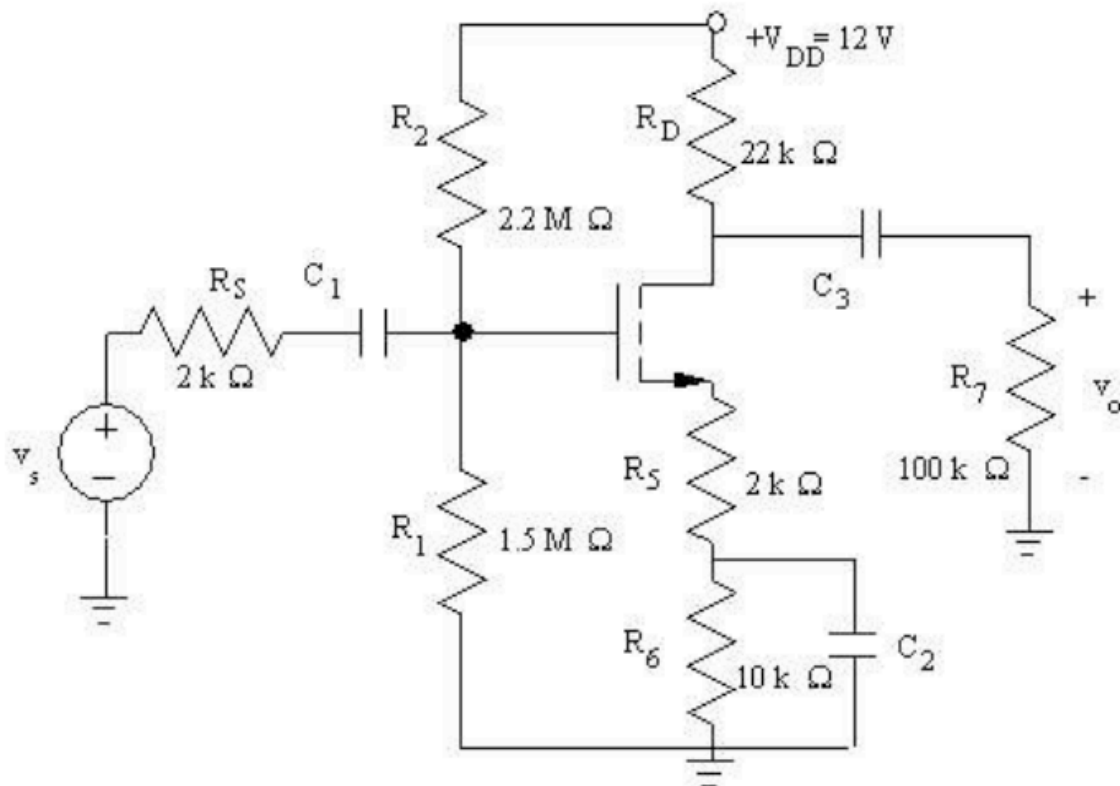
The analysis of an amplifier is usually divided into the DC analysis and the AC analysis. For both analyses, we have draw equivalent circuits. We will first consider DC equivalent circuits.

- d. In DC equivalent circuits, capacitors, coils, AC voltage sources, and AC current sources may be replaced by DC equivalents. Fill out the following table: (5 pts)

circuit element	DC equivalent	Explanation
Coil		
Capacitor		
AC current source		
AC voltage source		

Hint: For the coil and the capacitor and coil, remember what happens in the steady state. For the AC sources, think about what you know about the DC voltage or current at these devices.

In the following we will analyze the following single stage amplifier circuit:



- e. Draw the DC equivalent circuit for the given circuit. The source v_s is an AC voltage source. (5 pts)

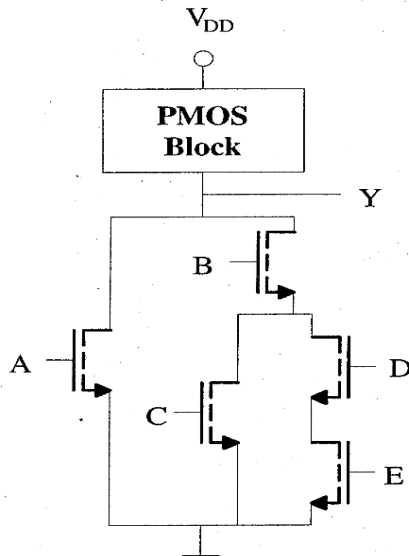
Aim of the DC analysis is to calculate the Q-point of the transistor, i.e. the voltage between drain and source and the current through the channel. The Q-point can then be used to calculate the transconductance and the drain resistance of the MOSFET which is needed for the small signal analysis.

- f. Calculate the voltage between the drain and the source as well as the voltage between the gate and the source. Further, calculate the current through the channel of the MOSFET. In which mode is the MOSFET biased? The transistor is an n-channel type. For this complete exercise, use the typical values of an MOSFET as given in the table on page 581 of the textbook. (10 pts)

Hint: As you have seen in c, there are three operating modes. Initially, it is usually not evident in which operation mode the MOSFET is biased. The usual analysis method is therefore an educated guess which is then verified by calculation. If the guess was wrong, there are only two other options...

III CMOS Logic Gates (30 pts)

Apart from the application in amplifier circuits, MOSFETs are also the most important building blocks of logic circuits. A modern graphical processing unit, for instance, contains more than 120 million transistors. Apart from the already discussed diode logic, there exists logic gates which are based on BJTs. Further, there exists logic exclusively using n-channel MOSFETs or p-channel MOSFETs. Our focus, however, will be on the so called CMOS, which uses both types of MOSFETs.



3. Given is NMOS block of a function implementing a boolean function. (15 pts)

a) What boolean function is implemented?

b) Draw the PMOS part of the circuit.

4. Construct a circuit which implements $Y = A \cdot (B \cdot C + D \cdot E)$ (15 pts)