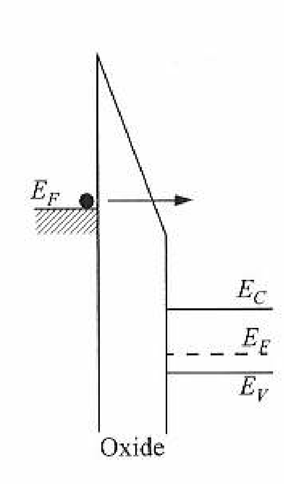
Problem 1: Memory

Fill in the following table for the advantages / disadvantages of various types of memories. Use the terminology 1= the best; 2= OK, but not the best; 3=problem: Volatile=Y/N.

	Read time	Write time	Clear time	Density	Volatile
SRAM					
DRAM					
Floating Gate (tunneling injection)					
Floating Gate (Hot carrier injection)					
Charged gate (tunneling injection)					
Stacked anti-fuse					
Phase Change					

Problem 2: Memory

The electron tunneling current through an oxide is given by Fowler Nordheim current with the barrier height between Si/SiO2 Φ=3.0eV, ε(SiO2)=4.2:



$$J = \frac{q^2 E^2}{16\pi^2 \hbar \Phi} \exp\left[\frac{-4\sqrt{2m^*}(q\Phi)^{3/2}}{3\hbar q E}\right]$$

a) How long would it take to turn a floating gate device with a turn on voltage of 1V and a 5V write bias through an oxide that is 5nm thick?

b) If hot electrons are used to charge the gate with ~1eV of energy above the conduction band, how long would it take to charge the same floating gate?

Problem 3: Scaling

If all physical lengths of a transistor geometry (Channel length, width and oxide thickness) are scaled as L' = L/a, how will the following elements scale?

a) Oxide Capacitance

b) Gate capacitance

c) Drain current Id

d) Circuit density

e) Circuit Speed (f)

f) Power density assuming that switching energy dominates with Power/transistor ~ CV^2f and voltage that also scales with geometry.

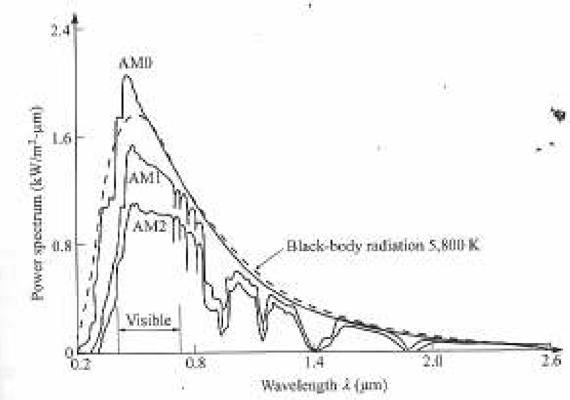
g) Power density assuming that switching energy dominates Power/transistor ~ CV^2f and voltage that does not scales.

h) Power density assuming that interconnect and channel resistance dominate and voltage that does not scale. Assume that the power/transistor = Id^2 R = Id^2 ρ L/A

Problem 4: Solar Cells

The figure below shows the spectrum of solar radiation. Assume initially that leakage, absorption and efficiency can be ignored. Which material would have the highest photo-induced current output? Why?:

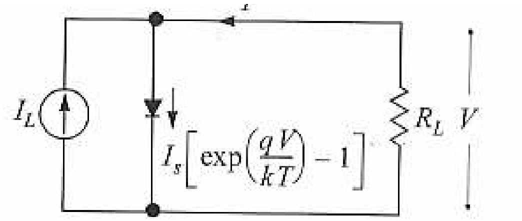
1) SiC (Eg = 3.0eV),
2) Si (Eg =1.1eV) 3)
3) PbS (Eg=0.4eV).



ig. 39 Solar spectrum at different air-mass conditions. (After Ref. 80.)

(B) Solar cells have the equivalent circuit shown below. Show that the open circuit voltage Voc (no current output) is given by the following where I_L is the photogenerated current, I_S is the saturation current of the PN junction.

$$Voc = \frac{kT}{q} \ln\left(\frac{I_L}{I_S}\right)$$



Problem 4 (part 2)

(c) Which material will have the largest open circuit voltage for the same doping levels of the PN junction? SiC (Eg = 3.0eV), Si (Eg =1.1eV) or PbS (Eg=0.4eV) Why? Recall that the saturation current of a PN junction has the form $I_S = I_0 \exp(-Eg/kT)$

(d) Assume that the solar spectrum due to black body radiation from the sun is proportional to exp(-hc/λkTs) at short wavelengths and λ^{-2} at long wavelengths (this is not exactly true). Ts is the temperature of the sun.

$$N(E) = N(hc/\lambda) = No\lambda^{-2} \exp(\mathrm{hc}/\lambda \mathrm{kTs})$$

Find the bandgap for maximum **power** output.

Problem 5: Magnetic materials

a) Sketch on the same graph the magnetic susceptibility of a paramagnetic, diamagnetic material and ferromagnetic material

b) Find the susceptibility of a magnetic material with the following magnetization. Ms and Hc are constants. Sketch the susceptibility and explain the significance of Ms and Hc.

$$M(H) = \frac{MsH}{Hc\sqrt{1+(H/Hc)^2}}$$

Problem 6: magnetic media

A disk drive has ~100GB of data. What is the required cohesive magnetic energy such that less than 1 bit is lost / day. Assume an attempt frequency for the magnetic spins of ~1E-14 s^{-1}. Assume a diameter of ~10nm for the domains. What is the required anisotropy exchange energy?

Problem 7: Read heads

A spin valve has a non magnetic layer between a pinned ferromagnetic layer and another ferromagnetic layer that can rotate with applied magnetic field. Explain the magnetoresistance of this device for current perpendicular to the layers and parallel to the layers. Which would have a larger magnetoresistance? Include diagrams.