Review for Exam 4

Information you may need:

h = 6.626 x 10^{-34} J s
k = 8.99 x 10^{9} N m^2/C^2
e = 1.6x10^{-19} C
m_e = 9.11x10^{-31} kg

hc = 1240 eV nm
1 eV = 1.602 x 10^{-19} J
R = 8.31 J/(K mol)
ε = 8.85 x 10^{-12} F/m

k_B = 8.62 x 10^{-5} eV / K
k_B = 1.38 x 10^{-23} J / K
k_B = R / N_A

$J = env_{de} + epv_{dh}$ $\quad v_{de} = \mu_e E_x$ $\quad v_{dh} = \mu_h E_x$

$$\mu_e = \frac{e\tau_e}{m_e^*} \qquad \mu_h = \frac{e\tau_e}{m_h^*} \qquad \sigma = en\mu_e + ep\mu_h$$

$$n \approx N_c \exp\left[-\frac{E_c - E_F}{kT}\right] \qquad N_c = 2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}$$

$$g_{cb}(E) = \frac{8\pi\sqrt{2}m_e^{*3/2}}{h^3}(E - E_c)^{1/2}$$

$$p \approx N_v \exp\left[-\frac{E_F - E_v}{kT}\right] \qquad N_v = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2}$$

$$np = N_c N_v \exp\left[-\frac{E_g}{kT}\right] = n_i^2$$

$$N_a W_p = N_d W_n \qquad \frac{dE}{dx} = \frac{\rho_{net}(x)}{\varepsilon} \qquad E(x) = \frac{1}{\varepsilon}\int_{-W_p}^{x} \rho_{net}(x)dx$$

$$E_0 = -\frac{eN_d W_n}{\varepsilon} \qquad V_0 = -\frac{1}{2}E_0 W_0 = \frac{eN_a N_d W_0^2}{2\varepsilon(N_a + N_d)} \qquad V_0 = \frac{kT}{e}\ln\left(\frac{N_a N_d}{n_i^2}\right)$$

$$W_0 = \left[\frac{2\varepsilon(N_a + N_d)V_0}{eN_a N_d}\right]^{1/2}$$

1. Explain the dependence of conductivity on temperature for conductors and semiconductors.

2. What is the difference between an intrinsic and an extrinsic semiconductor?

3. Explain why, for an intrinsic semiconductor, the electron concentration depends on the Fermi-Dirac distribution, f(E):
$$n = \int_{E_c}^{E_c+\chi} g_{cb}(E)f(E)dE \approx N_c \exp\left[-\frac{E_c - E_F}{kT}\right]$$
while the hole concentration depends on 1-f(E):
$$p = \int_{0}^{E_v} g_{vb}(E)[1-f(E)]dE \approx N_v \exp\left[-\frac{E_F - E_v}{kT}\right]$$

4. For an intrinsic semicondcutor, how are n and p related?

5. Where is the Fermi level in an intrinsic semiconductor in relation to the conduction and valence bands?

6. Sketch an energy level diagram for an n-doped and a p-doped semiconductor.

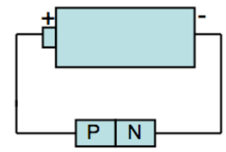
7. Where is the Fermi level in an n-doped semiconductor in relation to the conduction and valence bands?

8. Where is the Fermi level in a p-doped semiconductor in relation to the conduction and valence bands?

9. Based only on the desire to limit minority carriers, why would silicon be preferable to germanium as a fabric for doped semiconductors? The band gap for silicon is 1.1 eV, while that of germanium is 0.66 eV.

10. For intrinsic semiconductors, the intrinsic carrier concentration n_i depends on temperature as follows:
$$n_i \propto \exp[-E_g / 2kT]$$
a) Why (physically) is there a factor of 2 in the denominator of the exponential?
b) Show that for room temperature (T = 300 K) silicon with a band gap of 1.11 eV, a temperature rise of 4 K would raise the conductivity by about 30%.

11. It is often said that the transistor is the basic element of amplification, yet it supplies no energy of its own. Exactly what is its role in amplification?



12. Many new traffic lights use red, yellow, and green light-emitting diodes (LEDs) to save energy.

a. A traffic light needs three different LEDs: one to produce red light, one to produce green light, and one to produce yellow light. Above is a circuit for producing light from an LED. Describe how the electrons would flow through this circuit and produce light, and draw a representation of the energy levels/bands at the interface between the N-type and the P-type semiconductor which illustrates where the electrons are in energy as they flow through the semiconductors and which energy levels are filled with electrons that are not moving.

b. What would be different between the red LED, the yellow LED, and the green LED to produce the different colors of light?

c. If the yellow LED emits light with wavelength 580nm, what will be the approximate measured voltage drop across the diode (in volts)?

d. Older traffic lights use regular light bulbs with red, green, or yellow filters. Explain why using LEDs is so much more energy efficient. Include the physics principles and reasoning to support your answer.

13. A) Sketch an NPN transistor showing the depletion layer for a large negative, small negative, zero, small positive, and large positive control voltage.
B) Make a sketch of control voltage vs current.