Problem 1(Photoelectron)

Blue light of wavelength 300nm and intensity 0.5 W/m^2 is directed at a material with work function of 2.7 eV.

(1) Find the maximum kinetic energy (in eV) of the photoelectrons. (7%)

(2) If the quantum efficiency is 1% (meaning 1% of the incident photons produce photoelectrons), how many photoelectrons are emitted per second if the semiconductor surface has an area of 2cm? (8%)

Problem 2 (Quantum mechanics) (10%)

Write down the operators associated with the following observable quantities in quantum mechanics.

1. Position, x
2. Linear momentum, p
3. Kinetic energy, KE
4. Total energy, E
5. Hamiltonian, H. (assuming the potential energy is U(x))

Problem 3 (10%)

(a) For a hydrogen atom, the wave function can be assumed in the form of $\psi(r,\theta,\phi)=R(r)\Theta(\theta)\Phi(\phi)$ and the Schrödinger equation can be simplified with the method of separation of variables. Please derive the ground-state electron energy E_1 that corresponds to n (principal quantum number) = 1 and l (orbital quantum number) = 0.

(b) The wave function of a 1s electron is $\psi=\frac{e^{-r/a_0}}{\sqrt{\pi}a_0^{3/2}}$. Please find the average value of $1/r$ for an electron in the hydrogen atom.

Problem 4 (15%)

(a) The total potential energy in an ionic crystal is given by the equation: $U_{total}=-\frac{\alpha e^2}{4\pi\varepsilon_0 r}+\frac{B}{r^n}$. Please show graphically the potential energy of this equation and explain the origin of these two terms.

(b) Please calculate the value of the constant n for the NaCl molecule.
(The binding energy of this molecule is 7.95 eV/molecule. The equilibrium distance between Na^+ and Cl^- ions is 2.8 Å and the Madelung constant for the NaCl crystal is $\alpha=1.75$.)

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Problem 5

(15%) Please draw the energy band diagrams of a semiconductor p-n junction diode at (i) no bias, (ii) reverse bias (iii) forward bias, you need to include the conduction band, valance band, and Fermi level in your diagrams and put p side on the left.

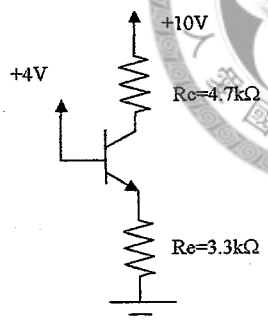
Problem 6

(10%) What is Fermi energy?

Problem 7

(a) (18%) For the following circuit biased at constant voltages, what are the base current, collector current and collector voltage?, assuming β =100, and base-emitter voltage of the transistor Vbe = 0.7V.

(b) (7%) From (a), please draw the small signal model using the simplified hybrid-π model.



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