

1. Please write down the time dependent Schrodinger Equation. (2 points)

If the wave function is  $\psi(x,t)$ , what is the expectation value of  $\langle x \rangle$ ? (4 points)

Please write down the definition of operator  $\hat{p}$  and  $\hat{E}$ . (2 points)

If the wave function of electron

$$\begin{aligned}\psi(x) &= A \cos\left(\frac{2\pi}{L}x\right) & -L/4 < x < L/4 \\ &= 0 & |x| > L/4\end{aligned}$$

What is the expectation value of  $\langle p \rangle$ ? (7 points)

2. Please write down the definition of uncertainty principle of position and momentum. (3 points).

If we want to measure the electron wave function in the resolution of  $0.1 \text{ \AA}$ , what is the minimum energy of the electron in unit eV? (7 points)

3. The Planck Radiation Formula is expressed as

$$u(\nu)d\nu = \frac{8\pi h}{c^3} \frac{\nu^3 d\nu}{e^{h\nu/k_B T} - 1}$$

If we treat the sun as a black body radiator at  $6000\text{K}$ , for simplification, we assume that  $h\nu \gg k_B T$ . What is the peak wavelength of the radiation spectrum emitted from the sun? (10 points)

4. (15%) The wave function of 1s and 2s electrons in the hydrogen atoms are

$$\phi_{1s} = \frac{e^{-r/a_0}}{\sqrt{\pi a_0^2}} \quad \text{and} \quad \phi_{2s} = \frac{e^{-r/2a_0}}{\sqrt{32\pi a_0^2}} \left(2 - \frac{r}{a_0}\right)$$

- (1) Find the average value of  $1/r$  for an electron in 1s state.  
(2) Find the position where possibility is the highest to find the 1s and 2s electron, respectively.

5. (10%) If  $\lambda$  is the mean free path between the collisions of a free electron and the average time  $\tau$  between collision is  $\tau = \lambda/V_F$ , where  $V_F$  is the Fermi velocity. Find the resistivity  $\rho$  in terms of  $m$ ,  $n$ ,  $e$ ,  $\lambda$ , and  $V_F$ . ( $m$ ,  $n$ , and  $e$  are the electron mass, density, and charge, respectively.)

6. (5%) What is the quantum number for singlet state? What is the quantum number for triplet state?

7. (5%) If the ground state energy of rotational levels of a molecule is  $E$ , what is the frequency of the emitted photons when it transits from the initial state of rotational quantum number  $J=3$  to the final state of  $J=2$ ?

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8. (5%) If in a system which has angular momentum  $L=4$  and spin quantum number  $S=1$ , what are the possible quantum numbers of total momentum  $J$  and its  $z$  component  $J_z$ , respectively?

9. 6% (a) Describe "the operation conditions" and "the current-voltage characteristics" of an enhancement-type MOSFET when it is operated in the cutoff region, the triode region, and the saturation region, separately.

(You may answer the questions in terms of the following parameters:

$V_T$ : threshold voltage,  $V_{GS}$ : gate-source voltage,  $V_{DS}$ : drain-source voltage,  $i_D$ : drain current,  $k_n$ : process transconductance parameter,  $W$ : channel width,  $L$ : channel length)

1% (b) Which region(s) is(are) used if the FET is to operate as an amplifier?

1% (c) Which region(s) is(are) used if the FET is to operate as a switch?

8% (d) Figure 1-1 shows the NMOS amplifier with a depletion load. Neglect the body effect in the load transistor  $Q_2$ . There are four distinct segments in the resulting voltage transfer characteristics,  $v_O$  and  $v_I$ , as shown in Figure 1-2. Please write down the modes of operation (cutoff, triode, or saturation) of FET  $Q_1$  and  $Q_2$  when the amplifier is operated in the region I, II, III, IV of the transfer characteristics.

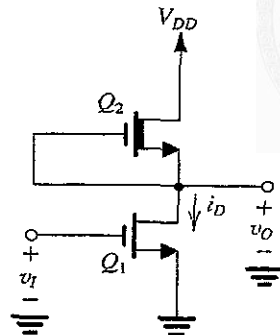


Figure 1-1

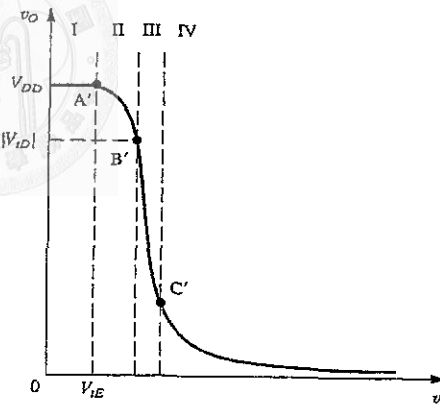


Figure 1-2

10. 9% Determine the currents,  $I_B$ ,  $I_E$ ,  $I_C$ , and the voltage at collector,  $V_C$ , in the circuit of Figure 2. Based on voltages and currents obtained, what is the operation mode of the transistor? Assume  $\beta = 99$ .

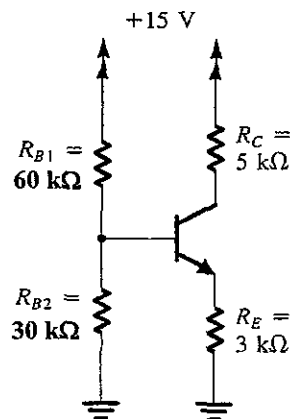


Figure 2